The Globalization of Science

The Place of Agricultural Research

New, expanded edition

Edited by

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and

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Foreword: Quo Vadis, Globalization of Agricultural Research?

The last one or two decades of this century can be described in many different ways, and the direction in which we are moving has been discussed in many different fora. However, there can be little doubt that worldwide globalization issues have been in the forefront of every discussion. Globalization means moving away from well-known, traditional structures, organizational forms, and hierarchies and entering the unknown; it means *change*. And just as we have seen change in the global economy, so should we also expect change in the global agricultural research system. It will not be static, but will change systematically and permanently. Flexibility and mobility will be needed, and vision must lead the way. The leaders in change and the early participants to this process will be the winners, but what about the losers?

Unfortunately, whenever there is change, there are winners and losers, and the various international initiatives that have come up in recent years have not always benefited every country equally. The initiatives regarding globalization have necessarily centered around the growth of national economies, and agreements have been made in such areas as commerce and trade. However, poor countries with basically traditional agricultural economies have not been able to reap the benefits expected from or promised by these agreements.

Realistic programs to provide sufficient support for most of the short- and medium-term losers in the development of a global economy are still missing, nor is there anything to ensure that in the long term—and as soon as possible—the current losers will gain from globalization efforts.

Agricultural research, as an essential branch of science, is the latest topic in discussions on globalization. For more than a century, agriculture and farmers have experienced changes, often radical changes. Traditionally, natural resources and labor were the only production inputs. In the second half of the 18th century, science-based agriculture started to displace traditional, knowledge-based farming. Capital inputs gained in importance: mechanization, new chemicals in the form of inorganic fertilizers and animal nutrients, new ways of combating pests and diseases, new plant varieties and better seed, and improved animal breeds. All of these helped increase the productivity of both land and labor; they decreased labor requirements and provided capital for—often rapid—industrialization. Earlier in this century, management became the fourth production factor, raising production and income or, at least, slowing down the otherwise fast-growing difference between rural and urban life, between agriculture and other sectors of the economy. Access to knowledge made possible by the revolution in information technology is the fifth factor.

Globalization of agricultural research can be expected in the very near future. However, it must be ensured that all countries and people, especially the poorest among them, will benefit. As most, if not all, of the very poor countries are agricultural countries, attempts to overcome poverty, to improve food security, and to protect natural resources must steer the globalization of agricultural research in the right direction, avoiding pitfalls and setbacks.

Early endeavors at building a global agricultural research system started about 25 years ago with the creation of the Consultative Group on International Agricultural Research: the CGIAR. Besides the Rockefeller and Ford Foundations, political leaders like Boerma of FAO, McNamara of the World Bank, and Hoffman of UNDP saw the need for international agricultural research efforts to overcome the threats of hunger and starvation looming in Asia. They succeeded in attracting Sir John Crawford of Australia, who, together with others, laid the foundation for a very specific global agricultural research system. Over the last quarter of this century, the system has been fortunate to find leaders for different needs and responsibilities, guiding and directing the system's development and its different facets. They gained valuable experience in international agricultural research and in early globalization efforts—experience that should be the basis for the further development of a truly global system. It is for this reason that ISNAR has contacted most of the early fathers of the CGIAR, requesting a contribution, based on their experience and vision, for forthcoming discussions about the globalization of agricultural research. Although the time for finalizing this book was very, very short, nearly all of those approached found the idea appealing, and have contributed.

ISNAR did not provide any guidance to the authors on the content of their contributions, other than simply inviting them to send a short paper sharing their vision of the future globalization of agricultural research. (The gist of this invitation is reprinted on the back of this book.) And while the authors have not covered every issue of concern in the discussions of globalization, they have dealt with some very important aspects of the globalization of agricultural research, especially regarding the past and future role of the CGIAR.

Some invited authors were not able to meet the deadline for the first edition of this book. However, we included them in this second, expanded version, which now covers certain aspects of globalization with regard to agricultural research that were missing from the first edition.

For some readers, it may come as a surprise to see the rather uniform central message that runs throughout most of these papers; others may have expected this result. But the message cannot be ignored: without more—and more effective and efficient—agricultural research at all levels, and without global partnerships, we will never meet the challenges of feeding the hungry, providing a living for the poor, sustaining and protecting our natural heritage, and providing the basis for all of us to live in comfort and security. The action to meet these challenges must start now!

The editors and ISNAR are very grateful to the many colleagues and friends who so willingly and often at very short notice contributed to this publication.

For ISNAR

Christian Bonte-Friedheim *Kathleen Sheridan*

Acronyms

ABSP	a USAID-funded biotechnology project, Michigan State University
APUKI	Agri Business Institution, Peru
ASARECA	Association for Strengthening Agricultural research in Eastern and Central Africa
ATBI	All Taxa Biodiversity Inventory
BIMS	Biodiversity Information Management System, Costa Rica
CAAS	Chinese Academy of Agricultural Sciences, Peking
CABI	International Centre for Agriculture and Biosciences, UK
CARDI	Caribbean Agricultural Research and Development Institute
CASDC	Committee on Agricultural Sustainability for Developing Countries
CATIE	Tropical Agronomical Research and Higher Education Center
CENPRO	Center for the Promotion of Exports, Costa Rica
CGIAR	Consultative Group for International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical
CIDIAT	International Center for Integrated Development of Land and Water
CIEH	Comite Interafricain d'Etudes Hydrauliques
CIFOR	Center for International Forestry Research
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo
CORAF	Conférence des Responsables de la Recherche Agronomique Africains
DEVRES	a consulting company
DG	director general
DMDP	a nematicide
DNA	deoxyribonucleic acid
EIER	Ecole Inter-Etats d'Ingenieurs de l'Equipement Rural
ELADA 21	Electronic Atlas for Agenda 21
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FGC	fast-growing country
GATT	General Agreement on Tariffs and Trade
GDP	gross domestic product
GEF	Global Environment Facility
GLIP	Grain Legumes Improvement Research and Training
GNP	gross national product
GWP	Global Water Partnership
HDGC	Human Dimensions of Global Change Program
HDGEC	Human Dimensions of Global Environmental Change Program
IARC	international agricultural research center
IARI	Indian Agricultural Research Institute
IBSRAM	International Board for Soil Research and Management

ICAR	Indian Council of Agricultural Research
ICARDA	International Center for Agricultural Research in the Dry Areas
ICBG	international cooperative biodiversity group
ICIBE	International Center for Insect Physiology and Ecology
ICID	International Commission on Irrigation and Drainage
ICLARM	International Centre for Living Aquatic Resources Management
ICRAF	International Center for Research in Agro-Forestry
ICRISAT	International Crops Research Institute for Semi-Arid Tropics
ICSU	international scientific union
IDRC	International Development Research Centre, Canada
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IGBP	International Geosphere-Biosphere Program
IIASA	International Institute for Applied Systems Analysis
IIBC	International Institute of Biological Control
IICA	Inter-American Institute for Cooperation on Agriculture
IIMI	International Irrigation Management Institute
IITA	International Institute of Tropical Agriculture
ILO	International Labour Organisation
INBio	National Biodiversity Institute, Costa Rica
INDENA	a phyto-pharmaceutical company, Italy
INIBAP	International Network for the Improvement of Banana and Plantain
INSAH	Institut du Sahel, Mali
IPF	IPM facility (a UNEP initiative)
IPM	integrated pest management
IPTRID	International Program for Technology Research on Irrigation and Drainage
IRRI	International Rice Research Institute
IUCN	International Union for the Conservation of Nature and Natural Resources
IUFRO	International Union of Forestry Research Organizations
MINAE	Ministry of the Environment and Energy, Costa Rica
NAFTA	North American Free Trade Agreement
NARS	national agricultural research system
NGO	nongovernmental organization
NORAD	Norwegian Agency for International Development
NRI	Natural Resources Institute, UK
NSF	National Science Foundation, USA
OECD	Organization for Economic Cooperation and Development
ORSTOM	Office de la Recherche Scientifique et Technique Outre-Mer
PRECODEPA	Programa Regional Cooperativo de la Papa
PROCIANDINO	Programa Cooperativo de Investigación y Transferencia de Tecnología Agropecuaria para la Subregión Andina
PROCISUR	Programa Cooperativo de Investigación Agrícola del Cono Sur
PROCITROPICOS	Programa Cooperativo de Investigación Agrícola de los Trópicos
R&D	research and development
RAI	regional agricultural research institution

RFGC	resource-poor, fast-growing country
SACCAR	Southern African Centre for Cooperation in Agricultural and Natural Resources Research and Training
SADC	Southern African Development Community
SADCC	Southern African Development Coordination Conference
SMIP	Sorghum and Millet Improvement Research and Training
SPAAR	Special Program for African Agricultural Research
START	System for Analysis, Research, and Training
T&V	training and visit
TAC	Technical Advisory Committee of the CGIAR
TWIG	taxonomic working groups
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNIDO	United Nations Industrial Development Organisation
UPLB	University of the Philippines at Los Baños
UPOV	International Union for Protection of Plant Varieties
USA	United States of America
USAID	United States Agency for International Development
WARDA	West Africa Rice Development Association
WASAD	FAO International Action Program on Water for Sustainable Agricultural Development
WCRP	World Climate Research Program
WHO	World Health Organization
WTO	World Trade Organization

Agriculture and Globalization: The Evolving Role of Agricultural Research

Christian Bonte-Friedheim, Steven R. Tabor, and Hélio Tollini

A combination of technological advance and economic policy convergence have fundamentally changed the business environment for agriculture, both in developed and developing nations. Globalization has ushered in an era of rising importance of international trade and commerce, of supranational policy accords, rules, and regulations. At the same time, it introduced a relative decline in the powers and authorities of individual nation states and governments.

Governments have tended to craft for their countries special policies to nurture agricultural growth and development. They do this because agriculture is different from the other economic sectors. It depends on various natural conditions, social good arises by maintaining food security, and there are values attributed to maintaining rural traditions and cultural preferences for particular types of foodstuffs. Environmental attributes are associated with green countrysides and there are social benefits of stable rural employment. Added to this list would clearly be the recognition in low-income countries that agricultural growth provides a powerful boost to economic development, incomes, employment, poverty reduction, and equity.

Globalization, however, is gradually eroding the scope for autonomous, national agricultural policy making. Global competitiveness will more and more determine the nature and scope of agricultural opportunities. As technological innovation has long been the principle means of improving competitiveness, agricultural research will play an increasingly important role. But globalization will also radically change the operating setting for agricultural research in ways that are likely to lead to greater concentration of top-tier scientific effort.

A powerful engine of growth, globalization promises ample rewards for those most able to take advantage of new technologies and expanding market opportunities. But for many poor countries, globalization may come as a shock—if not a setback—particularly in those instances in which agriculture is far from being globally competitive. Agricultural research has a special role to play in poor countries, but the research that is needed may be well beyond the reach of national institutions. Globalization promises to inspire new sources of supranational agricultural research expertise, especially the ever-growing private sector. Some of this talent could be harnessed to address the needs of agriculture in the poorest nations, but to do so will require new and innovative modes of development assistance.

Globalization as a Context for Agricultural Research

What has now come to be described as globalization is, in a very strict and narrow sense, the growing role of international commerce and cross-border investment activity (World Bank 1993). But the contemporary phenomena of globalization goes well beyond this to encompass

- a dynamic set of processes that increase the linkages and interdependence of national economies (OECD 1994)
- deep integration amongst nations involving the harmonization and possibly coordination of economic policies and domestic laws and institutions (Brookings Institution 1996)
- world economic, political, cultural, and social integration (IMF 1997)

The main forces underlying this process of globalization include

- international trade liberalization
- free flow of capital and investment liberalization
- technological advance in communications and transportation
- convergence towards market-friendly economic management systems
- development of global media and business practice standards
- easing of superpower political tensions
- the formation of regional and other supranational trade and cooperation entities

The global economy, polity, and social order are built on a host of integrating arrangements made by sovereign states. The institutional fabric of globalization—or more precisely the rules and regulations governing global exchange—is still evolving, and it is doing so at vastly different paces in different countries. The last great episode of economic globalization—in the late part of the 19th century—provides ample lessons of the fragility of global institutions.

In the late 19th century, global trade flows increased as colonial empires became entrenched, industrialization got underway, and railroads integrated most of North America, East and Central Europe, India, and Russia. Industrialization fueled demand for raw material imports, while countries competed for the foreign investment capital necessary to build railways. Common trading institutions, such as the universal gold and silver standards, commercial codes, bilateral trade treaties, and reciprocal foreign investment policies, were adopted to reduce transaction costs of global commerce.

But two world wars, the commodity price depression of the 1920s, financial instability between the wars, the great depression of the 1930s, as well as the spread of state planning, authoritarianism, and militarism brought the free trade era to a near halt. By 1950, there were only five countries in the world with convertible currencies, one-third of the world's production was in socialist economies, and half of the world's output was in countries with state-led industrialization.

Liberalization certainly did not occur quickly after World War II. By 1960, only 20 percent of global GDP was produced in countries that were classified as generally open economies. The rest was produced in countries with restricted trade regimes, socialism, or other variants of state-led industrial development.

Between 1960 and 1993, there was a process of gradual trade liberalization. The so-called G6 and the G24 countries began to meet to coordinate economic policy. Thousands of bilateral and regional trade agreements were struck. At the same time, the application of modern fiscal and monetary management techniques in Europe, North America, Japan, and other parts of East Asia led to the restoration of macroeconomic stability and currency convertibility. By 1993, close to 60 percent of global GDP originated in open economies. With China and Russia liberalizing, the share of global GDP from the open economies could rise in 1997 to as high as 83 percent, or about the same level as that prevailing one hundred years earlier.

During this period of post-war liberalization, the developing and transition economies were relatively late to liberalize. The more affluent industrial economies liberalized access to imports and exports, reduced tariffs, but then developed new (and more discretionary) forms of trade protection, such as anti-dumping laws, voluntary trade restraints, countervailing duties, and a range of quality and phytosanitary controls (Sachs and Warner 1995).

But this has clearly changed in the late 1980s and early 1990s. Fred Bergstren (1997) describes the 1990s as the era of competitive liberalization. He notes that 60 percent of global trade is now under free trade agreements, and more than 100 such agreements are registered with the General Agreement on Tariffs and Trade (GATT) and the World Trade Organization (WTO). Global interdependence is increasing, thanks to revolutions in technology, transport, communications, and even, to a certain extent, politics and ideology. There is capital mobility on an unprecedented scale. To quote Bergsten (1997), "Success in today's global economy requires countries to compete effectively in international markets rather than simply at home."

Increasingly, that competition is knowledge-based, and the degree to which countries are able to generate or tap established sources of knowledge will determine their success or failure in the international economy (World Bank 1997). The phenomena of globalization has reminded policymakers and industry leaders that their success or failure will hinge very much on knowledge-capital, and that research and development systems—the traditional sources of new knowledge—will have a very important role to play indeed.

Globalization's Effects on the Agricultural Research Environment

Internationalization has been a long-standing tradition in the agricultural sciences. The generation and diffusion of agricultural technology, for national development purposes, has long been a topic of great concern to both agricultural policymakers and agricultural economists (Stephan 1996). With increasing awareness of the importance of globalization, a number of economists have attempted to quantify the importance of technology inflows (Bayoumi, Coe, and Helman 1996) and have compared the importance of inflows to locally generated research and development (R&D) outputs (Brennan, Singh, and Lewin 1996; Maredia and Byerlee 1996; Mywish, Ward, and Byerlee 1996). But while analysis of agricultural technology spillovers helps illustrate the importance and ease of cross-border R&D flows, it does not fully capture the implications of changing international conditions on the creation of truly global markets for agricultural R&D services.

Agricultural R&D has always been, in part, a global enterprise. For technology embodied in capital goods—fertilizers, pesticides, seeds, and mechanical technology—the private research and development effort has been led by a handful of multinational chemical, seed, and machinery companies. While the research activities of these companies have traditionally tended to be concentrated near corporate headquarters and major markets, outsourcing of trans-border technology and subcontracting of research has now become common practice. Private agricultural research expenditures are now well in excess of public expenditures in most member states of the Organisation for Economic Co-operation and Development (OECD). In fact, the R&D expenditures of several agribusinesses can be as great as that of the institutions of the Consultative Group on International Agricultural Research (CGIAR) as a whole. In terms of public agricultural research—through projects of the CGIAR and other organizations (such as the multilateral development banks and bilateral aid agencies)—close to half a billion US dollars per year is dedicated specifically to global agricultural research initiatives. The amount spent by national programs on international research investments exceeds that dedicated by international donors to global agricultural research efforts, although attempts to define boundaries between R&D expenditures for national versus international purposes prove difficult (Brady 1996, Yudelman 1996).

Global agricultural research efforts of the past were, in many ways, institutional responses to problems of high transaction costs and barriers to market entry. The CGIAR and other international institutions were designed to apply the breeding, agronomy, and other agricultural husbandry skills available in the West to the agricultural problems confronting developing nations. The initial payoffs of the green revolution were sufficient to convince financiers that such initiatives were a good investment in economic growth and poverty alleviation (Yudelman 1996). For private firms, international R&D exercises have been used to ensure that products would not be denied market access on grounds of quality or safety certification (Hagedoorn 1995, Walsh et al. 1996).

But the new wave of globalization is very different. As noted above, it is being driven by changes in the economic, technologic, and political landscape that have very little to do with agriculture or agricultural research per se. This is producing a decentralized wave of agricultural R&D globalization, driven more by changes in market conditions, technology, and scientific opportunity than by intergovernmental attempts to bridge imperfect markets. As a result, new and different global agricultural R&D enterprises are emerging. These can be categorized in a number of ways:

- *Leading edge vs. routine problem solving.* A number of "leading-edge" initiatives have been launched, such as the global rice-genome mapping project and the United Nations GIS initiative. These initiatives have attracted international participation, partly because such tasks were too costly for single nations to accomplish and partly because they have been in the areas of basic or strategic research where the gains are difficult to privately appropriate. But there have also been a number of routine problem-solving global initiatives, such as the Asian rice breeding network and the cassava mealybug control network. Through these initiatives, a number of nations have simply pooled resources to resolve what are deemed to be public-good agriculture R&D problems. These more routine initiatives tend to be regionally centered and predominately in the areas of animal health, plant protection and pest control, resource management, and food production—the traditional mainstays of intergovernmental cooperation.
- *Formal vs. informal.* While the number of formal global initiatives continues to rise, the true explosion in global activity has come from informal collaborations between groups of like-minded scientists communicating, for example, via the Internet. It is estimated that approximately three million scientists already have Internet facilities and that by the year 2010, more than 90 percent of the globe's scientists will have access to the Internet (Forge 1995). Much of the Internet-based scientific collaboration is informal, both in a contractual sense and in the sense that goals and objectives are not clearly defined. Signs of the growing importance of informal global collaboration can be found in the rising trend of cross-national citations in scientific publications (Hagedoorn 1995).
- *Capacity complementing vs. predatory globalization.* While many global efforts augment skills shortages or otherwise complement national capacities, scientific globalization also has a predatory element. Many developing countries have traditionally suffered from a loss of scientific human resources from national to regional or international programs. The very recent loss of some of the best scientific talent from Eastern Europe and the former Soviet Union to global public and private enterprise is now recognized as a significant cause for concern (Etzkowitz 1996, Foster and Sottas 1996).

The free-wheeling or more decentralized nature of the current wave of globalization has caused many to wonder who may be a technological winner and who a technological loser in this new environment. Changes in basic and strategic research, in particular in genetics and biotechnology, have ushered in an era in which both genes and scientific processes are now regularly patented. While the degree of agricultural patent protection varies widely, the private appropriation of both scientific results and scientific processes is likely to reduce the stock of leading-edge technology available for free in the public domain.

Weaker parties—in particular those countries with very limited scientific capability or with tightly constrained environments for scientific work—may be at an increasing information disadvantage in the new global agricultural research setting. Some of the weaker parties may find their scientific capacities reduced by "brain poaching" on global markets. Scientific institutions that are not of global quality may find that they have no role to play. National governments that are too weak to exert much influence on global research outcomes may withdraw support for research efforts (Nickel 1996, Leclercl and Gagne 1994).

Globalization creates supranational markets for knowledge capital (World Bank 1997). In simple terms, the supply and demand for agricultural R&D services can be defined in terms of a market for a home and for an imported, global good (see figure 1). In poor countries, in countries with little agricultural activity, or in countries with limited potential for scientific investment to impact on growth or resource conservation (i.e., in nations with abundant natural resources), the demand for agricultural R&D will be less than in countries in which agriculture is prominent, discretionary incomes significant, and R&D-based innovation a potent source of growth. The supply curve S for national agricultural R&D services is largely a function of the human capital stock and of the productivity of the scientists employed in national organizations.

The international supply curve for agricultural research products is effectively horizontal up to the point at which new, tailor-made competencies must be created. It is horizontal through a relatively long range, because R&D outputs embodied in seeds, pesticides, fertilizers, machinery, and other private agrocapital goods would tend to be supplied at the marginal cost of innovation (which is small in large markets). Other reasons for the long horizontal range of the supply curve are that many global technologies (e.g., free-for-the-asking R&D) are public goods, and even patented technology can be imitated relatively easy. The global supply curve begins to "kink upward" at the point where a task or issue is not yet in the global domain or when global R&D outputs for that issue have yet to be generated. For example, one could imagine that a global R&D solution could be crafted for a disease resistence problem in a commodity only consumed in one small country. But to do so would involve mobilizing molecular biology talent to work on this problem at a relatively high cost.

Prior to globalization, the aggregate agricultural R&D supply curve would be the horizontal summation of the home good and the "rest-of-the-world R&D" supply frontiers. The aggregate unit cost of agricultural R&D is given as an equilibrium at point P in figure 1, the domestic supply at Q_1 and the imported, or global supply, at Q_1Q_2.

What, then, are the likely implications of globalization? The demand curve for agricultural R&D is likely to shift out, because (1) traditionally, incomes and relative prices change and (2) investments in technology are one of the few "green" measures that countries may use to advance agricultural growth without incurring the wrath of the WTO. Greater global competition will inspire private demand for productivity-enhancing measures.

On the supply side, the main shift occurs in the global supply curve for imported R&D services. The global supply curve will tend to shift out due to a fall in transaction costs, vast improvement in scale economies in R&D production, a rediscovery of past R&D outputs, and a reduction in barriers to trade in goods and technologies among increasingly interdependent nations. Second, the point at which the global agricultural R&D supply curve would begin to kink upwards would also shift outwards due to (1) global advances in knowledge and capital-intensive R&D approaches in fields, such as molecular biology and computer simulation, (2) exploitation of scale, scope, and network economies in global endeavors, and (3) improvement in R&D investment efficiency as more investment becomes concentrated on the best global providers of different R&D services.

Possible effects of an outward shift of the global R&D supply curve are provided in figure 2. Since globalization lowers the cost of aggregate R&D

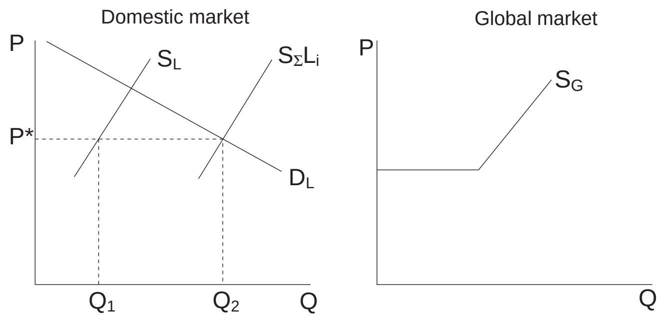

Figure 1. Pre-globalization supply and demand for agricultural R&D

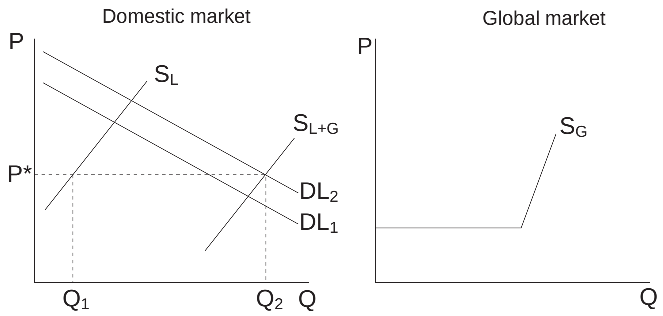

Figure 2. Post-globalization supply and demand for agricultural R&D

services, the winners will be those who benefit—very early—from improvements in agricultural productivity. Countries, consumers, and producers all stand to gain as agricultural productivity rises. In this stylized picture, the net result of globalization would be to reduce demand for domestic R&D service providers, lower the overall unit costs of aggregate R&D services, and increase national dependence on global sources of R&D. In equilibrium, excess national R&D capacity would be absorbed in other fields or "rebalanced" to become competitive on global markets.

In a more globalized R&D marketplace, what would be demanded from national R&D service providers would be in those areas where local providers are either internationally competitive sources of new technology or where, for reasons of location or special capacities, they provide a service truly unique to local markets. Even with globalization, local agricultural R&D suppliers may continue to be preferred over global R&D sources. In certain areas, the local supply price will be lower than the global supply price. Barriers to technology flow may persist, and countries may continue to subsidize national initiatives for strategic reasons. Such strategic reasons could include the desire to ensure that a particular country has the capacity to take advantage of global R&D developments (Leclerc and Gagne 1994). It may also simply be a fear that global R&D sources are less secure (or politically malleable) and that the future of a country's food supply and the well-being of the farming community should not be subject to disruptions in relations amongst nations.

But in many cases, globalization will increase competition in the provision of agricultural R&D services. As it does, so arises the question of whether different segments of national R&D capacity can and should be preserved. This question is largely a matter of comparing the trade-offs to investing in improving the productivity of national R&D enterprises (research institutes, universities, R&D wings of private companies) or financing provision of R&D services from global service providers. This is very much an issue of the economic trade-offs prevailing at the kink in the global supply curve, because that is the point at which global capacity has either not developed or not generated an output that can compete with R&D outputs supplied locally.

What would global agricultural R&D capacity look like at the kink? Frank and Cook (1995) suggest that this may well be a market in which the winners—the best and the brightest—may come to dominate. The reasons for this are relatively simple. The market for the best providers of R&D services would increase substantially through globalization. Around the world, agricultural R&D consumers would prefer to buy the global best R&D output, especially if its cost is relatively low (i.e., is in the horizontal segment of the global R&D supply curve). As the market for the best providers widens, their reputation would increase. This, in turn, improves their ability to attract the funding support needed to make the investments in human and physical capital necessary to stay at the top of their fields.

As privatization of technology generation and diffussion increases, economic considerations will tend to prevail over political or nationalistic approaches to agricultural technology problems. This will tend to increase local confidence in the availability and suitability of supranational sources of technology supply. As this learning process occurs, the size of the market for the best providers will widen.

Hence, for countries seeking to transform redundant agricultural R&D capacity into globally competitive capacity, the challenge is unlikely to be one of competing with the run-of-the-mill national agricultural research service, but more one of competing with the best and the brightest of the existing global institutions.

But if global standards are set relatively high, and if this leads to a concentration in the agro-R&D industry amongst a small number of top-flight institutions, then this implies that the fixed costs of shifting the kink in the global supply curve will be quite high. The main reason for this is that the cost of buying the time and attention of the winners working at the kink of the global R&D supply curve are probably fairly high. But shifting this kink, either locally or through global service providers, is likely to emerge as a key challenge in maintaining technological competitiveness in agriculture.

Managing Risks and Uncertainties

There are different risks and uncertainties that countries face as they integrate their scientific efforts with R&D offered on global technology markets. These risks can be divided, for ease of exposition, into three categories: (1) agricultural technology neglect risk, (2) performance risk, and (3) market failure risk.

As globalization proceeds, policymakers (in particular in large countries) may become convinced that international sources of technology supply—what is likely to be the growing, private market for agricultural technology—is sufficient to meet countries' needs. Furthermore, as more and more agricultural technology is offered by the private sector, governments may see little reason to fund research that the private sector is already taking on. Policy neglect of agricultural technology generation is likely to result in a less-than-optimal rate of agricultural development. Reasons for this are that (1) a great deal of agricultural research is area specific, (2) national R&D capacity is required to control, screen, select, and adapt new technologies to local conditions to maximize benefits, (3) while there may be an abundance of international technology on the market, it may not be terribly suitable for a particular nation's resource endowment, and (4) even a small degree of government involvement in technology generation may help offset possible tendencies towards predatory pricing and market discrimination policies by the private sector.

A second technology risk associated with globalization is what can be termed performance failure. Market processes involve what Joseph Schumpeter described as a form of creative destruction, when established processes and businesses become obsolete and are replaced by new, innovative forms of capital and suppliers. Good performers are well rewarded, while bad performers are forced out of the market. But in the case of agricultural technology for essential food commodities, the question is whether the farm sector—or the consuming population as a whole—can afford the risk that technology is to be provided by a R&D entity that is not performing adequately. The farm community may not have backup sources of agricultural technology, especially if they have come to depend on a particular source of public research or private agribusiness for their needs. On the other hand, consumers can only process or consume what is actually produced.

The third risk is that countries will become dependent on global sources of agricultural technology, but that these markets will not meet national needs or will cease to function. The global market may lead the global R&D supplier to search for new production processes that are irrelevant for the conditions in a given country. So, good technology may not even be adapted because it is too far away from what is feasible in a particular country. Even in those cases where global technology does meet a country's needs, the flow could be disrupted by international disputes of one kind or another, or simply because changed economic circumstances caused countries to be periodically unable to afford imports to which they have become accustomed. In the case of agricultural technology generation, it may be quite difficult to substitute domestically generated research for international research because of the long gestation lags involved in establishing R&D institutions and the capital-intensive nature of modern scientific research. Science policy leaders should be aware of this risk of market disruption. They should define and maintain superfluous local capacities as a backup against global R&D provision failure. Such backup strategies may also help cushion the fall in national agricultural R&D supply in areas that become non-competitive by global standards.

Policy Lessons

Although globalization clearly results in agricultural technology risks, it also offers significant opportunities for technological gain. Producers, industries, and countries obtain access to a broader and more diverse range of scientific service providers. The greater the range of institutions in the technology market, the greater the likelihood that technology solutions can be tailored to the needs of particular groups. Competition amongst technology providers can lower costs and inspire greater user responsiveness. The creation of larger markets for technology outputs will lead to economies of scale in R&D production and will enable research efforts to be mounted that would be too large for any single nation to bear.

Globalization is having a profound effect on the operating environment for agricultural research. Policymakers must be aware that this is occurring, anticipate the changes that will affect agriculture and science, and craft an appropriate policy response. A great deal of learning will be required to operate effectively in the emerging global economy. Agricultural leaders will need to examine the competitiveness of their agricultural sectors very closely. Depending on the country and the commodity, some agricultural subsectors will flourish in global markets, and others may be forced out-of-business. Agricultural leaders face an important task in assisting those subsectors that can take advantage of widening global markets to do so, and, by the same token, assisting the noncompetitive sectors to find appropriate alternative sources of income and employment.

But the reaction of agricultural policy to globalization must extend beyond the provision of better technology to the expanding subsectors and diversification technology to subsectors that are declining in economic importance. As noted above, globalization will create new market-based opportunities for cross-border generation and exchange of agricultural technology. As the global market for agricultural research grows, science policy leaders must learn to be well informed consumers, quality certifiers, as well as producers of public-good agricultural research. Science policy leaders will need to develop the public-sector capacity to increasingly test and certify that agricultural research products that are privately generated are not harmful to people or nature, that new technologies are superior to old ones, and that private technology-product claims are accurate and realistic. Science policy leaders will need to learn to contract in and contract out agricultural research services, to procure technology that is privately patented, to foster cross-border partnerships, to protect the property rights on international suppliers of technology, and, ultimately, to redefine what technology development services are supplied locally and what is produced from international sources.

Reaping the benefits from global advances is by no means automatic. To benefit from global sources of agricultural R&D, countries will need to have in place a regulatory and stimulating environment that enables cross-border R&D flows. Facilitating technology in-flows is the first stage. This implies, at a minimum, conformity with emerging standards for intellectual property rights, biosafety, phytosanitary standards, and trade in technology (Nickel 1996). But going beyond this, countries that are more plugged in to global initiatives will determine the portfolio of global competencies, and will be the first group to be exposed to global products or services. A more active, second stage of global integration implies that countries need to identify and supply agricultural scientists of a global standard and ensure that those scientists are effectively linked to global initiatives and networks (Leclerc and Gagne 1994).

Diversifying the financing sources for agricultural research may help to reveal the degree to which global R&D markets are a viable alternative to national R&D systems. If, for example, stronger farmer groups are called upon to pay for (at least a part of) their technological needs, they will tend to select the best source of technology, whether it be internally or externally supplied.

In the developing world, there are three categories of countries: those that will prosper in a globalized economy quite easily, those that can potentially prosper if appropriate agriculture and R&D policies are adopted, and those that are likely to be marginalized by globalization. Countries in the first category are those whose agriculture sectors are already quite competitive, with reasonably unrestricted foreign trade, with a strong indigenous agricultural knowledge base, and a tradition of encouraging foreign investment in technology-sensitive sectors. The second group are those countries in which significant shifts in agricultural resource allocation will be required to tap into global markets and which have limited experience (other than as development assistance recipients) in tapping global agricultural technology markets. These countries are more likely to be followers than leaders in globalizing their agricultural technology generation effort, but this is probably of little consequence given the learning processes that will need to be accomplished.

Globalization will also generate technology losers, most notably those countries with barriers to technology inflows or with inadequate capacity to participate actively in global initiatives (i.e., groups two and three listed above). One solution is to improve policies that allow countries to integrate with a rapidly growing global agricultural economy. This is the solution that the IMF (1997) advocates and defines as engagement policies. For agricultural research, such policies might start simply with efforts to establish intellectual property rights regimes, to open technology imports to the private sector, to ensure that laws, rules, and standards applied to the environment in the industrialized countries are established, and to ensure that mechanisms for off-shore sourcing of agricultural technology (by government, for example) are put into place.

But the more serious concern is for the third group of countries (or groups of producers), which, despite the best of engagement policies, are still likely to remain on the margins of an increasingly prosperous global economy. These countries may find that despite innovative technology and rural development efforts, their comparative advantage does not lie in agriculture. Or they simply cannot afford to tap into international sources of agricultural technology and run perpetually behind productivity leaders in the main global commodity markets. Or they may have very limited natural resources or with inadequate domestic capacity to search for or capture technology readily available on international markets. Finally, they may be countries in which the narrowness of subsistence-oriented agricultural markets simply provides producers with no incentive to break into the larger cash economy, even if there are no policy or regulatory barriers per se to their entry into such markets.

Conclusions

International attention will be required to ensure that the developing world is well integrated and well served by the forces unleashed by globalization. It is in the international interest to do so, not only because of the potential contribution that can be made to social objectives such as poverty reduction and environmental stabilization, but also because the prosperity and stability of the global economy depend very much on the breadth and depth of participation by all participating countries. Those countries with very little to gain from engaging the global economy have very little to loose by disrupting it.

Global assistance initiatives in agricultural research could help countries anticipate the changes in agriculture and in agricultural R&D that are likely to arise with globalization. It could help those countries with the potential to tap into global sources of R&D for agricultural development purposes to do so by crafting appropriate policies and projects that link national and international R&E to markers. The real challenge, however, will be to ensure that the benefits of globalization are widely shared by all countries and most people. International assistance efforts could help reduce the adjustment costs to the "losers" by

- financing the costs of global "kink-shifting" tasks most relevant to the needs of the poor (and nonplugged-in) nations,
- promoting capacity development and capacity agglomeration strategies that facilitate participation in global efforts
- helping poorer nations frame agriculture and R&D strategies that anticipate the challenges and opportunities stemming from globalization.

For such assistance efforts to be effective, new modes of providing agricultural technology aid will need to evolve. Narrow, nationalistic interests that lead either to the creation of flag-flying institutes or support to home-country institutions will need to give way to efforts aimed more at creatively tapping and deploying appropriate public and private agricultural research expertise-wherever that expertise happens to reside. Helping science systems craft the policies and create the physical and institutional infrastructure needed to link effectively into the global R&D scene (as opposed to creating capacity to duplicate efforts more efficiently undertaken elsewhere) is another important initiative not only for agricultural R&D providers but for the whole development assistance community.

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Christian Bonte-Friedheim had a long career in international agricultural development. He started with the German technical assistance program in the planning division of the Ministry of Agriculture in Kenya and as assistant to the minister. He worked for 20 years with the Food and Agriculture Organization of the United Nations (FAO), where his final assignment was assistant director general in charge of the Agricultural Department. For the last seven years, until his retirement in early 1997, he was director general of ISNAR. Steve Tabor and Hélio Tollini are senior officers in ISNAR, both with a long career in international agricultural development, including assignments in institutions such as the International Fund for Agricultural Development, the World Bank, and the Inter-American Development Bank.

Quo Vadis International Agricultural Research

Nyle C. Brady

My vision of the future of international agriculture research is illuminated by two major factors: the obvious degree of globalization in other areas of human endeavor and my perception of what is needed to accommodate the dual challenges of meeting human food requirements and of maintaining or even improving the quality of our environment. These factors are compounded further by the major differences among ecosystems, countries, economies, and people who characterize our globe.

Globalization of Communications, Economies, and Science

There is no question but that the world in which we live today is dramatically different from the one that gave birth to the CGIAR 25 years ago and to the Green Revolution that followed. In no phase of human interaction are the differences greater than in the degree to which barriers between people, countries, economies, and different scientific communities have broken down. The revolution in international communications with the ever-expanding cyberspace linkages through the Internet and World Wide Web has the potential of doing more to enhance the international exchange of ideas, concepts, trade, and science than any process the earth has ever known.

Advances in communication are rivaled only by the development of economic linkages that cross borders in both the North and the South. An increasing portion of the world economy and political activities is controlled or influenced by private or public institutions with anchors in more than one country. Large multinational corporations are increasingly dominating private economies, while regional (e.g., the EU) or global (e.g., UN-related) public institutions take the lead in marshalling the power of the public sector. Everything is becoming more and more interrelated. No longer do the activities of people in one area of the world concern only the citizens of that region. These activities affect not only the *people* in other regions but can have significant impacts on nonhuman species and on the natural resources upon which all creatures depend.

Cross-country economic and political interactions have helped stimulate similar interchanges in the scientific community. For example, advanced research in physics, such as that for the superconducting supercollider, involves cooperation among scientists from many different industrialized countries. UN-sponsored scientific workshops and conferences that focus on modeling, with its implications for estimating potential global warming, provide data and judgments useful to political leaders in making national and international decisions on the release of chemical contaminants to the atmosphere.

The creation and growth of large multinational corporations have both positive and negative implications for global science. From a positive point of view, these firms generally have strong research and development arms that are involved in both applied and basic research. This is research that can have benefits across national borders and which commonly involves scientists from different countries. The negative aspects of the growing private-sector involvement in research is that its findings are generally proprietary, and are initially of primary value to the commercial concern alone. Agriculture is being influenced both positively and negatively by the growth of private-sector research, especially research utilizing genetic engineering and related biotechnology.

Agriculture's Dual Role

A vision as to how agricultural research can effectively take advantage of the global changes taking place around us will depend on what research is to be done in the coming decades. First and foremost, agriculture must continue to provide access to an abundance of reasonably priced food for an ever-increasing human population, some one billion of whom live in poverty. This can be done by increasing food production and by simultaneously increasing the purchasing power of people so they can buy the food.

The second challenge to agricultural research is to help maintain or even improve the integrity of the natural resources upon which agriculture and other sectors of society depend. Reductions in the rate of soil degradation must receive high priority, as must efforts to reduce uncontrolled runoff of water and to increase the efficiency of water use for producing food. Chemical pollutants from agricultural sources must be reduced, as must the slashing and burning of natural forested areas to permit subsistence farming. The process of converting naturally vegetated areas to cultivated lands must be reversed in many fragile land areas around the world.

Increasing Access to Food

The challenge of reducing hunger and poverty is fully as great today as it was 25 years ago. In fact, in some ways it is greater. Even though the rate of increase in the human population is going down, the absolute numbers being added every year remain at about 90 million, and 90 percent of these are born to low-income parents. The example set by some progressive developing countries of letting agriculture become the stimulus for overall economic growth must be followed by others.

Means must be found to provide food, not only for the expanding population but to accommodate increased per capita food requirements as rising incomes expand the consumption of food, particularly of animal products. For example, rising economic growth in Asia is increasing the demand for meat and other animal products, a demand that can be met only by producing or importing larger quantities of feed grains. China's remarkable economic growth in recent years has stimulated phenomenal increases in meat consumption and concomitant increases in grain imports (Brown and Flavin 1996).

Factors Influencing Increased Food Availability

What are the major sources of increased food production in the coming decades? It is not likely to come from increased areas of cultivated lands. Constraints on expansion of land under cultivation are greater today than they were 25 years ago. In Asia, where population numbers are rising rapidly, there is little uncultivated land suitable for shifting to agriculture. In fact, expansion of cities and of the industrial sector is removing some of the most productive lands from agriculture.

The rate of increase in irrigation, a second major force in stimulating crop production in the past three decades, has slowed dramatically since the 1980s. In fact, in some countries areas under irrigation are declining because overexploited underground water sources are being abandoned.

Fertilizer usage, another prime contributor to increased food production, leveled off in 1990 after 10 years of phenomenal increase worldwide. In some countries, rates of fertilizer use have actually declined. Furthermore, as yield levels approach a crop's potential, the yield response to additional increments of fertilizer declines, making it less profitable to apply chemicals. This situation pertains in many countries.

Continued poverty limits access to food for more than one billion people. John Mellor (1995) once again reminds us of the critical importance of agricultural development to kick-start domestic economies. He cites six developing countries that have used agriculture successfully as the leading edge of growth for overall economic development. These countries used yield-increasing and cost-cutting technologies to achieve their goals.

The decline in the influence of these major factors, as well as many minor ones, on increased food production has depressed the rate of growth of national and global yield and production levels. For example, in the United States grain yields that increased more than 40 percent in the 1950s are increasing at a rate of only 10 percent in the 1990s (Brown 1996).

These constraints on increases in food production, along with adverse weather conditions and political unrest in some parts of the world, have resulted in a near stagnation in grain production worldwide. A leveling off of grain yields coupled with increased food consumption has greatly reduced the carry-over stocks of grain. In 1996 they reached a new low, enough to provide only 46 days of consumption. Grain prices responded by rising 25 percent (Pinstrup-Anderson and Garrett 1996), an increase of greatest detriment to poor people (urban as well as rural) who commonly spend 50 percent and more of their income on food. Whether this food scarcity is only temporary is uncertain, but it does emphasize the critical global importance of continued increases in food production.

Changes in the Environment

The challenges to achieve agricultural growth without degrading the quality of our natural resources are at least as great today as they were 30 years ago, and will likely become even more important in the future. Green Revolution technologies had both positive and negative effects on environmental quality. The major positive effect was the creation of new technologies that greatly increased crop production on the relatively flat land areas. While some have criticized such emphasis on favored areas, the net result was high production from areas not so subject to soil erosion and water runoff. The added production reduced the need to cultivate the less-favored sloping upland areas where soil degradation is often rampant. High yields per hectare in the lowlands have probably done as much to constrain soil erosion in upland areas as have direct measures aimed at improved management of these erosion-prone areas.

Green Revolution technologies also had negative effects on environmental quality. We now know that the misguided emphasis on chemical pesticides to manage crop pests not only had little overall positive effect on the production of most food crops, but resulted in the contamination of soil and water, in serious health problems for the applicators, and in adverse effects on nonhuman species. A major objective of the coming decades is to help farmers get off the pesticide treadmill and develop integrated pest management systems that minimize or even eliminate the use of pesticides.

Excessive chemical fertilizer use can also have negative environmental effects. Cultivators following fertilizer practices that pay off economically may apply far more inorganic nutrients than the plants can use. The excess is either tied up in the soil or moves in runoff or drainage water into streams and lakes where eutrophication and even damage to human health can occur. Nutrient management systems that better match the timing of nutrient supply with that of plant uptake are essential if optimum yields and environmental quality goals are to be attained.

A third detrimental effect of intensive agriculture on environmental quality relates to irrigation schemes in arid areas that are not properly drained. In time, salt buildup in the soil becomes excessive, constraining yields or resulting in the ultimate movement of salts back into the streams. While increasing salt tolerance of the crops to be grown may provide temporary relief, ultimately such systems will need proper land drainage if the areas are not to be abandoned.

There is some evidence of a reduction of land productivity in areas of intensified crop culture. A reduction in the productivity of wheat/rice systems in South Asia is an example (Pagiola 1995). Only by increased applications of chemical fertilizers have production levels been maintained. Research is under way to ascertain the production constraints in this region and to find ways to remove them. Over much wider areas, soil erosion has reduced the productivity of steeply sloping upland soils. Steps must be taken to develop practical farming systems that will reduce this wasteful loss of our valuable natural resources.

Pollution of near-shore marine resources coupled with gross overexploitation of ocean fisheries has resulted in a general leveling off of marine fish harvests. The world per capita fish harvest peaked in 1989 and fish prices have risen in response (Garcia and Granger 1996). The harvests of preferred fish such as cod, haddock, and flounder have declined, being replaced by lower valued species. Expansion in aquaculture, especially in Asia, has helped arrest the decline in marine catches. Research to improve the productive capacity of aquatic species is still in its infancy and must be pursued vigorously if the protein requirements of poor people are to be met.

Public Support for Agricultural Research

One last constraint that must be overcome is the decline in public support for agricultural research. Such decline is noted in both the North and South. The relative abundance of food supplies in industrialized countries, coupled with increased private-sector funding of research in some sectors, is used to justify relative declines in funding for agricultural research. But in most developing countries, where drastic reductions in public support for agricultural research has taken place, there are no compensating increases in private-sector support for scientific activities. Furthermore, decreases in foreign aid by some donor nations, particularly the United States, have compounded the budget problems of research institutions serving the developing countries. The overall decline in support for agricultural research must be reversed if the food needs of the future are to be met.

Vision of the Future Agricultural Research

My vision of the future of agricultural research focuses on what should be done in an environmentally sustainable manner to remove the food production constraints just discussed, and how it can best and most efficiently be done. I suggest that the major focus will be on five areas.

1. Increasing the Yield Potential

No other food production goal has been more important nor will be more important in the coming decades than increasing the potential yields of food crops and domestic animals. In the long run, this goal is just as important to environmental harmony as it is to feeding an ever-growing population. The short-statured, stiff-strawed cereal varieties of the Green Revolution must now be matched by similar yield-stimulating improvements in plant and animal species. Attempts being made by IRRI scientists to reengineer the rice plant with goals of 20 to 25 percent increases in yield potential are an example of developments to come (IRRI 1996).

While much of the impact of such developments will likely be felt on the more-favored land areas, less well-favored areas can also be affected. First, the need for using some fragile lands for food production can be reduced or even eliminated if production on the more-favored areas can be enhanced. Second, there is also great potential for increasing production in some of the less well-favored areas. For example, food production in vast areas of the tropics currently constrained by excess soil acidity and concomitant high levels of aluminum could be greatly increased by developing crop strains that are tolerant of high levels of aluminum. Similar constraints resulting from high or low temperatures, drought, and excessive salts could be removed if genetic tolerance to the constraint could be developed. While considerable progress has already been made in developing this tolerance, the availability of biotechnology and genetic engineering tools could greatly accelerate further developments in the future. The ability to transfer genes from one species to another opens up new doors of opportunity to developing crop cultivars that will grow well where we want them to grow.

While inputs from all disciplines will be needed to increase yield potentials, the foundation for such improvements will continue to be focused on germplasm enhancement, augmented by the rapidly changing tools of biotechnology and genetic engineering. To take full advantage of these tools, a variety of linkages will be forged with scientists and institutions working on upstream research and downstream product development. The institutions may be in the South or in the North and they may represent the private as well as the public sectors. Reluctance of both international and national research institutes to deal extensively with the private sector will be overcome. While care must be taken to protect the rights of farmers and of the research institutions and scientists in developing countries, full advantage will be taken of the rapidly expanding scientific frontier, as well as the efficiencies of the private sector in the areas of product development and distribution.

International agricultural research centers (IARCs) have a key role to play in enhancing global linkages in research to enhance yield potential. They will link more effectively with scientists in more advanced research institutes in both the North and the South to become aware of the most beneficial research techniques and to encourage the focus of those techniques on problems of developing countries. They will also link with those in both the private and public sectors who improve germplasm and disseminate it to farmers. Concrete agreements will be formalized among the collaborators to help farmers in developing countries fully realize the benefits of modern science. Lastly, the IARCs will observe all elements of safe practice in the use of biotechnology and will have constant dialogue with host-country regulators. The IARCs will continue to seek a common front on genetic resource issues and work with others in the South and the North, and in the public and private sectors, in developing plans for the future.

2. Management of Pests

The management of pests by means that not only enhance crop and animal production but reduce or eliminate the use of environmentally damaging pesticides is a shining part of the vision of the future. Pest management research can contribute handsomely to goals involving both food production and environmental protection. Scientists can contribute to this vision by gaining an understanding of the life cycles of both the pests and their enemies and can elucidate points of weakness in those cycles upon which control methods could be based. Likewise, scientists will create plant and animal strains with broad-based host resistance to diseases and insect pests. Working with farmers and extension specialists, researchers will help design integrated pest management (IPM) systems that result in high production and minimize the use of chemical pesticides.

The global orientation of IPM systems has already been initiated. Stories of successful IPM programs in one country are already being quickly disseminated to nearby and overseas counterparts. FAO, having helped stimulate reasonably successful national and regional pilot IPM operations, has joined with the World Bank, UNDP, and UNEP in initiating a global IPM facility (IPF). IPF will help developing countries and donors establish farmerbased IPM programs that are likely to minimize the use of chemical pesticides. Research findings will continue to underpin these pilot programs, and scientists will learn from them.

Interaction between the private and public sectors will be essential in the process of enhancing IPM. Some of these interactions may not be harmonious since IPM will likely decrease sales of those pesticides having serious detrimental effects on humans and other creatures. The suppliers of these chemicals will resist reductions in their use. More positive interactions will be expected, however, from other elements of the private sector that are already developing diagnostic tools and biological control methods more amenable to IPM objectives. IARCs will continue to cooperate with institutions, private or public, that are helping to develop such methods.

3. Soil, Water, and Nutrient Management

Great strides will be made in developing soil and crop management systems that provide plants with water and chemical nutrients in a timely manner so as to minimize the movement of water, nutrients, and the soil itself off the land to downstream areas of deposit. Practical systems will be developed to maintain vegetative cover on the soil during periods of heavy rainfall. Forage crops for animal production will help provide the soil cover. Genetically improved cover crops and live terrace barriers will help hold water on the land and thereby reduce soil erosion. In some areas, nearby fuelwood lots will provide cooking fuels for families, making it unnecessary for farmers to remove crop residues from their soils for cooking purposes. A combination of research and community action will be necessary to maintain vegetative cover on soils.

Research on methods to control the availability and release of chemical nutrients to growing plants will be accelerated. Increased emphasis will be placed on strategic combinations of organic and inorganic sources of these nutrients. In some very infertile soils, the supply of relative sedentary nutrients such as phosphorus may need to be provided by large applications of slowly available rock phosphate, treating this product as a capital investment. The World Bank is giving consideration to pilot field trials to evaluate such a procedure in parts of Africa.

Control of nitrogen-release rates will also receive priority attention, using combinations of organic and inorganic nitrogen sources. Special attention will be given to better understanding the role of soil organic matter, which may be the key to long-term management of the availability of nitrogen and associated nutrients.

Competition among agriculture, domestic users, and industry for the increasingly scarce supplies of water will force greater research attention to be given to increasing the water-use efficiency of crop plants, a process that is currently most wasteful. Soil and crop scientists will seek cultivars and cropping systems that reduce water waste from crop plants and from farm plots. Irrigation scientists and engineers will work with farmers and water-use associations to reduce the disgraceful waste of water in most irrigation schemes in developing countries. Farmers will be invited to join in participatory research schemes to improve the efficiency of water delivery systems. Farmers will likewise be better prepared to begin to pay more for their irrigation water—a likely future result of increased competition for this water.

International linkages will be essential to plan and implement research on soil, water, and plant nutrients. Since there are fewer improved products that could provide profits for input suppliers, the private sector will likely be less involved than it will be in research on genetic improvement. However, the economic principles guiding the private sector will be used increasingly in planning and implementing soil and water nutrient management. IARCs will take the a leadership role in carrying out research to better illustrate the economic value of sound soil and water management to society.

Water resources will likely receive more systemwide attention than has been the case in the past, especially in relation to the effect of food production systems on water quality and to coastal zone management. Undesirable pollutants coming from agricultural operations will be scrutinized.

4. Natural Vegetation Management and Conservation

Research on the conservation of soil and water on agricultural lands will be complemented by research to enhance land cover with forest and natural grassland species. The century-long transfer of such natural areas to agriculture will be arrested worldwide, and reversed in many areas. Research will be implemented to help move slash-and-burn farmers into more sustainable pursuits, either in forested areas or in more stable land areas. With the help of farmer participants, alternatives to some destructive slash-and-burn practices will be found and put to use.

Research in natural resource management will attract the attention of scientists from different disciplines but will likely be supported primarily by the public sector. Enlightened private-sector institutions might well be involved, however, in planning and implementing pilot activities based on research findings. In any case, linkages will be created between research institutes in the North and the South in attempts to shortcut efforts used in the past to enhance afforestation, as well as efforts to improve the production of existing forests.

5. Policy-Related Issues

Agricultural scientists will continue to play major roles in the setting of policies relating to food and natural resources. They will provide decision makers with assessments of the probable impacts or consequences of alternative courses of action. They will respond to requests from national and international institutions for background information on which decisions can be made, but will also make assessments on their own. Modeling research on fisheries is an example of the kinds of investigations and service that are invaluable to fishers, their associations and countries, and to the world as they attempt to arrest the decline in marine fisheries in most parts of the world. The IARCs will continue to remain independent nonpolitical voices interacting with private and public institutions in the policy-making process.

6. Research Methodologies and Partners

The diversity of research partners will continue to be expanded in the future. More and more, these partners will include other than traditional agricultural scientists. Basic physical scientists concerned with disciplines such as biochemistry, biophysics, and the atmospheric sciences will increasingly become members of teams seeking solutions to agricultural problems. Likewise, anthropologists, sociologists, and basic economists will be called upon to help agriculturalists better understand the people for whom they are working, and the economic and social systems with which they associate. The circle of the “old boys clubs” that tended to dominate IARCs of the past decades will be enlarged to include specialists from a range of nontraditional disciplines, and will include an increasing number of female scientists. For example, the degree to which leadership in genetic engineering research has been taken by nontraditional agricultural scientists and institutions provides a taste of what can be expected in the future.

The active involvement of farmers and their local organizations and leaders in planning and implementing some agricultural research projects will continue and will expand. Such involvement will not only help researchers better understand the needs of their farmer cooperators but will help them focus on developing solutions that might well be used later by farmers. Farmer involvement will be helpful in most areas of research discussed in this paper, but will be especially pertinent in research to improve pest management, soil, water, nutrient management, and the management of natural vegetation.

Conclusions

Two major goals will guide agricultural research in the decades ahead:

- increase the availability of food;
- maintain or enhance the quality of the environment.

To help achieve these goals, science must make even greater contributions in the coming decades than were made in the past 30 years. Global interactions among scientists of different disciplines and cultural backgrounds will be essential. Likewise, increased formal linkages will be forged between the public and private sectors to achieve these goals. The public sector will continue to provide primary support for the issues involving long-term conservation of natural resources, while the private sector will join in supporting research that involves profit-making products for use in agricultural systems. The globalization of agricultural research will involve an expansion of partners among supporters, scientific disciplines, participating cultivators, associated businesses, and the general public. IARCs will continue to evolve their programs, staff, and leadership to take advantage of globalization underway in almost every field of human endeavor.

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The CGIAR and World Food Supplies

Peter Brumby

Improving the science that underpins world food production is the immensely important task of the CGIAR. The magnitude of that responsibility resides in the observation that, across the world, inadequate food production in poor countries remains the single greatest cause of human misery.

An Uncertain Food Situation

It is true that Malthus is the current looser in the game of projecting food production. In most countries, famine, disease, and war have yet to check population growth in the manner he envisaged. There are, however, important exceptions. “Environmental exodus” is now the fate of an appreciable number of national and ethnic groups. Most pundits envisage no early change in world food security, but the law of opposites is the basis of social endeavor, and that law suggests it is frequently prudent to reassess one’s position.

Consider how wrong recent prophecies on food production have been.

In 1946 and 1947, it was widely believed that a lasting shortage of food was the fate of a war-shattered Europe. In the mid-1970s, the same fate was thought imminent in India. These notions were wrong. Worse, they led to further ideas that were seriously flawed. Many then believed, and some still do, that a complicated future can only be resolved by the detailed planning of an economy. Planning agencies proliferated within and beyond the UN system. In reality, this emphasis on planning proved a most successful means of ensuring a minimal connection between what was needed, and what was produced.

The second large misconception focused on world trade. In the 1950s, it was universally believed that the developing countries would provide the world’s food basket and that the developed countries would provide the industrial factories. A quite contrary result occurred. Exports of meat and milk products from Europe, and grain from North America, now overwhelm producers in other regions and countries.

The World Bank, FAO, IFPRI, OECD, and the Worldwatch Institute are the current players in the game of guessing where world food supplies are heading. Amongst this quintet, the Worldwatch Institute is the modern-day

Malthus. It is particularly concerned about the erosion of the agricultural resource base. It is also worried by the size of its projections for the grain import needs of China.

By contrast, the World Bank believes world food supplies will be abundant so long as investments in agricultural research are maintained. But the bets of FAO, OECD, and IFPRI are hedged. These organizations occupy the middle ground. Each shares the views of the Bank regarding the need to encourage further increases in agricultural productivity, and each agrees that further investment in agricultural research is the best way to achieve this. But in saying this, they are acutely aware that the degree of food self-sufficiency in developing countries will decline. Their consolation is that they believe this decline will be adequately compensated by an increase in the tradable surplus available in the advanced economies.

Such optimism is encouraged by the large production increase of recent years, a period characterized by the adoption of the broad range of technologies associated with the Green Revolution, and with the overpricing of food production through the production, consumption, and export subsidies provided by relatively wealthy countries. Less optimistic observers worry that the Green Revolution, and high subsidy policies, have now passed their peak impact. Further production increases might not be so easy.

The food cycle has been around a long time. Part of the cultural heritage most nations share, in one form or another, is the parable of seven years of plenty followed by seven years of lean. In spite of the lessons of history, cyclical swings in food output persist, and they result from, and further distort, investment decisions in matters agricultural.

As part of the syndrome of donor fatigue, a period of forgetfulness is currently underway amongst those responsible for financing agricultural research. It is an easy trap to fall into, mainly because the impact of inadequate agricultural research on agricultural production is blunt. There are large and uncertain time lags between research spending and improvements in agricultural output.

CGIAR Objectives

In considering the policy issues critical to progress in agricultural productivity, it is sensible to start by defining the recipe for increasing agricultural production. Back in 1991, the *Economist* did this particularly well: it noted part of the formula is to invest in new technology, part is to avoid environmental degradation, part is to stop subsidizing urban growth at the expense of farming, part is to let farmers import, unhindered, the equipment and chemicals needed to farm more efficiently, part is land reform, part is providing greater access to credit, and part is encouraging more education, which also helps curb population growth. Other participants seek to add gender and equity issues, biological diversity, extension practices, and on a broader scale, political, financial, and market stability.

Few would dispute the need for such a broad mix, but there are two snags for the CG system in accepting such an approach. The first, as any competent animal or plant breeder will tell you, is that multiple objectives result in very slow progress in any one component The trick the breeders use is to weight each part of a multiple objective with economic values. In that way, emphasis can be given to the bits that are really important.

The second snag is to decide on what these economic weights should be. To a landless villager seeking feed for his only cow, continued access to a degraded but useful grazing area of common land may be of vital importance. This same land is also likely to be of great importance to the conservationist concerned with biological diversity and sustainable land use. The issue here is that survival is the understandable priority of subsistence farmers caught in the poverty–land-degradation syndrome. Escape from that predicament depends on finding ways to increase the cash income of subsistence farmers sufficiently to enable them to use yield-increasing practices.

The conclusion is simple: the conflict between preventing starvation in the face of a continuing expansion of the size of human groups living on an insufficient land area, and safeguarding the longer-term productivity of that land, can only be resolved by continually increasing land productivity. And that is the major objective the CGIAR must promote.

Managing the CG System

To protect the integrity of the CG system, there is an extensive machinery of guidance. In addition to the supervisory role of the trustees of each center, the work of each center director (DG) is probed by program committees, guided and watched over by TAC, frequently reviewed by various external assemblies, and constrained by donors who use special funding to delineate the activities they will support. The impact of this extensive machinery of governance is predictable. It results in an emphasis on short-term research, on projects where the objective, and the results obtained, are easy to see. Inevitably, the role played by innovative, time-consuming, risky, early-stage research is diminished.

The role of center management is also changed by the governance process. It is tempting to argue that the earliest DGs were mainly scientists who, through scientific achievement, rose to leadership responsibility. Their background and inclination was to seek inspired innovation, such as changing the architecture of crop plants. In contrast, the demands now imposed on center directors encourage greater management skills: DGs are now expected to set and attain pragmatic and achievable goals in specific time frames.

These two differing styles of control produce different patterns of output performance. In the former, the products of innovative thinking are greater, a willingness to accept research risk is apparent, and sadly, a significant proportion of unsuccessful research efforts is likely to result. The philosophy is one of the productive carrying the less productive, of the good carrying the bad. With "managed science" the tolerance for ideas that don't work is less. It probably results in better utilization of center resources, in more outputs reported, and in fewer real advances. In short, it is a scenario that sustains steady but unspectacular growth. More critically, it may result in mediocrity.

The notion that inspiration cannot be programmed, and the belief of most donors that they need greater accountability of the funds they provide, are two sides of an awkward equation. The old arguments that research is not done by committees, that the DNA structure was not unravelled by a carefully constructed and time-bound research plan, that Rutherford had no thought that his work on splitting the atom would provide the key to understanding photosynthesis, carry little weight with donors, nor with many boards of trustees. But unusual ideas, reflective thinking, and plain good luck are the substance of real progress.

Not unreasonably, a sound strategy, clear priorities, and a sharp focus are the ingredients sought by good managers. They also seek a record of success in the research teams they back. What is less frequently acknowledged is that research directed to increased food production involves a very complex set of interrelationships, the interactions of which can be quite unexpected. No matter that great care may have gone into picking the strategic issues and priorities each center should tackle, flexibility in changing these when it becomes clear the chosen pathway is unproductive, is essential.

The bottom line is simple, the main road to productive research is to have first-class scientists working on important problems, well backed by a sound infrastructure, stable funding, and imaginative administration.

Collaborative Research

The case for the CG centers working more closely with national research groups has been made many times; it is widely acknowledged as a most desirable objective. The centers have excellent facilities, information systems, and scientific capability. These are strengths many national systems lack. Often, what they do have, however, is an extensive but underfunded staff, coupled with diversified field facilities plus a profound understanding of local constraints. A closer partnership between the centers and national systems, based on a carefully crafted regional strategy, and the provision of research contracts for which national groups might bid, appears worthy of further investigation.

In essence, there is a case for the centers to act, in part, as contractual funding agencies to national research groups.

Future Needs and Limitations

The paradox provided by an oversupply of food in the industrialized countries, an undersupply in developing countries, and a growing export trade in meat, milk, and grains from the former to the latter at prices that disadvantage local production is a formidable challenge. This anomaly provides the cushion that enables the industrialized countries to shield themselves from reality—that the demand for food is set to soar in the next generation.

Population growth is only part of the cause. Rising living standards disproportionately increase the demand for meat and milk, products whose output, in the developing countries, has been mainly improved by bringing further land and animal numbers into use. But this reserve capacity has now largely disappeared.

And one result of that disappearance is an escalating conflict between the need to safeguard the long-term productivity of agricultural land while feeding a continually expanding population.

Improving the agriculture of deeply traditional societies, where men tend the animals and women grow the crops, involves much more than the CG recruiting more bright research scientists. It requires a CG capable of saying *no* to wild economic policies, as well as supporting rational ones. The cooperatives and villagization of Ethiopia, the *ujama* of Tanzania, the state ranches of Zambia and Kenya, and the more extreme aspects of land reform in Latin America are ideas that, predictably, didn't work. And no amount of good research could change that.

In much the same way, transport constraints in some areas make it impossible to provide fertilizer and other inputs to better farming, or to provide access to market outlets for improved crops. Recognition of where research can be helpful is as important as recognition of what sort of research might help. The sins of commission in research are as profound as those of omission.

The focal point for any further globalization of agricultural science is the CGIAR. The needs of that group are simple: more members, more collaboration, more money, more informed debate.

The activities of the CG can never be a substitute for the role of national agricultural efforts, but it can provide the intellectual support system for agriculture that many poorer countries need. The major task for the CG is to seek the big breakthroughs required to achieve greater land productivity. Without that, the poverty trap that engulfs so many subsistence farmers will result in a further expansion of the "environmental exodus."

About the Author

Peter Brumby earned his PhD in animal physiology and genetics. After working for nine years as a researcher in his native New Zealand, he joined FAO, where he helped establish the Livestock Research Programme of the Agricultural Research Institute of Cyprus. He then took over regional responsibility for FAO's livestock activities in Latin America. In 1966 he was appointed director of the World Bank Livestock Project in Chile, and in 1968 he went to Rome as chief officer of the FAO/IBRD Livestock Group. From there he moved to the World Bank as a senior agriculturalist and livestock specialist. He became director general of ILCA in 1981 and served in this position for five years.

Beyond Technology

Just Faaland

The ongoing globalization of agricultural research is a process of extending its scope and reach in terms of geography, crops, environment, markets, and groups of producers and consumers; it is also a matter of research methodology and focus. Simply stated, the point I want to make in these notes is that the *context* has become as important as the specific *technological content* of agricultural research.

The Vision of the CGIAR is that of a world in which all members of the human family have access to food, are blessed with good health, and benefit from judicious management of natural resources. This is, of course, much more than ensuring a global—or even national—balance of food supplies and effective food demand; it calls for a change in patterns and volumes of both production and consumption to bring about a system that is also environmentally sustainable and provides household food security for all.

Clearly, the research agenda, now more than ever, needs to include study and analysis of the structures and workings of the economic, social, and political life within which the agricultural sector operates: the focus being on the interaction between agriculture and other sectors, both at local and wider (macro) levels.

The CGIAR research institutions, in cooperation with NARS and the private sector, have traditionally concentrated their research on technological development for particular crops—and with remarkable success in many cases. This will—indeed it must—continue as a major thrust of CGIAR research. Yet, as is acknowledged in the CGIAR itself, technological advances alone—while clearly helpful, even essential—have not been sufficient to eliminate household food insecurity on a massive scale in the developing world. Moreover, in working out the implications of actions foreseen in the pursuit of the objectives of its vision for the coming quarter century, the CGIAR itself finds that hundreds of millions of people—perhaps no fewer than today—will remain seriously undernourished or worse. If the CGIAR Vision is to be taken seriously as a guide to action within and beyond the system, our research must be widened and refocused so as to be relevant also for action to meet the basic food needs of the vast populations now projected to be seriously undernourished. Some shift in focus and emphasis is in evidence in the rhetoric, even in the exercises of priority setting within the system—all of which is a welcome first step—but there is very little so far in actual operation. While I put this forward as a characterization of the CGIAR today, not as a criticism of its managers and financiers, I lament the relative neglect in CGIAR research of the massive household food insecurity of those hundreds of millions who do not directly benefit from technological advances through agricultural research, which would still be the case even if these advances were to be accompanied by significantly accelerated agricultural investment.

Granted, the CGIAR could decide to remain an actor—and an important one—in the advancement of agricultural technologies through research, explicitly leaving to others the search for effective actions to specifically meet the needs of the hungry millions. This would leave the CGIAR with a clear mandate and an important function, but as I see it, it would also represent a serious case of lost opportunities. Throughout the CGIAR system, not only in IFPRI, scientists are concerned about the impact of their research on the income and employment of poor farmers, not only on the output gains that are made possible. Their actual research agendas are in some measure—possibly increasingly—conditioned by such concerns. This momentum, it seems to me, can be and should be strengthened, not set aside by again limiting the mandate of research to straight productivity and production advances in agriculture. A few illustrations will have to suffice:

Within the CGIAR and IFPRI, in particular, there resides a capacity and potential for research contributions to the policy debate on how to meet the basic food needs of poor people beyond their effective market demand, both through investments in agriculture-related nonfood sectors (e.g., transport and rural infrastructure) and through creation of gainful employment elsewhere in the economy.

Experience, analysis, and projections within and beyond the CGIAR clearly show that supply- and productivity-oriented agricultural research have the potential to make major contributions; they also clearly show the limits of such research in bringing about food security for all. The question inevitably arises whether other productive sectors are more likely than agriculture to make inroads on poverty and food insecurity. No one disputes that development will need to be advanced on many fronts simultaneously, but it is a question of how and where to strike the balance of investment and attention. For many years now, agriculture has lost out in competition for resources. One reason, I suggest, is that we have not been effective in explaining—and even worse, in exploiting—the potential of agricultural research to contribute to poverty alleviation and food security *beyond* the enhancement of output and productivity of food production.

As has been demonstrated again and again, in poor rural societies, investments in research and infrastructure, supportive of increased productivity and output of basic food-crop agriculture, are often of strategic importance in improving food security and livelihoods in general. The fact that the agricultural sector can play such a role in the dynamics of development, particularly at the early stages of development in an agrarian economy, gives credence to our claim in the CGIAR that resources spent on agricultural research have the potential of high returns.

Yet, I suggest, this general case for our cause needs to be validated for the specific research investment or activity proposed: Who will be in a position to make use of the new technology, new seeds, or other inputs? How will the benefits, costs, and risks be distributed? Will there be losers as well as winners?

My plea is for CGIAR centers to be more concerned about questions of this nature. Of course, the CGIAR system and individual centers are not oblivious to such questions, but more needs to be done not only by a specialized center like IFPRI, but also in the commodity centers where agricultural scientists can interact with social scientists in the planning and implementation of the research agenda.

In recent years, CGIAR centers have moved in this direction—some more than others. There is still a long way to go, however, before the exploration of the potential impact of our research portfolio on poverty and food security is advanced, as a matter of routine, so as to effectively inform our choices—and convince our financiers. Again, the knowledge to do so is available within the system, perhaps also within each center; the need is to resolutely decide to make the change.

Some technological research conducted by CGIAR centers is tailored to the specifics of given physical and social environments and therefore is likely to produce results directly applicable and relevant in the field. I suggest this can become a more frequent occurrence, *inter alia* by even closer collaboration with NARS. Moreover, an integral part of CGIAR research projects—not just an add-on—should be an assessment of the impact of technological advances and breakthroughs on poor farmers and, more widely, on food-insecure people.

CGIAR centers all cooperate with NARS institutions and thus gain and provide support for improved research effectiveness and impact. Such partnerships can strengthen the institutional capacity in developing countries to do their own research, in particular by the exposure it gives for colleagues from NARS to advanced research approaches and generally to the wider world of specialized agricultural research. All CGIAR centers contribute to building NARS in this manner; in recent years perhaps this has been done increasingly and in a more determined manner. In addition, ISNAR has the special and explicit mandate to assist NARS in building and effectively operating their respective research systems. All of this is to the credit of the CGIAR; however, my feeling is that the CGIAR has roles and activities that are underplayed relative to research on specific areas of output production.

While the mandates of the CGIAR centers are firmly focused on research, the NARS are more directly linked to extension structures and operations in their respective countries—or, at least, this is so in the more effective structures for advancement of agriculture through technology development and dissemination. Thus, for CGIAR centers, NARS can provide a most important link to the problems and potentials of farmers', which can help ensure the relevance of research programs and their impact in the field.

I do not suggest that CGIAR centers are unaware of this or that the value of this link is ignored, but urge that it be given greater attention when the centers' programs of action are developed and research priorities are set, and particularly when specific research projects are formulated and implemented. This would require more and broader consultation at the national level with NARS and—where possible, through them—with their sister structures for extension. Specifically for ISNAR, in its support of the building of strong and effective

NARS, ways and means should be sought to help strengthen the interaction at the national level between research and extension, which is often weak and ineffective.

A final illustration of what might be a more decisive shift in the CGIAR's research orientation would be to take on in a serious way the analysis of options for food aid and transfers more generally within and between countries. While for such analysis the link to agriculture as a production sector and source of employment and livelihood is evident, the research would also go beyond such interaction.

Here again, the CGIAR would not start from scratch. Experience and insight are available and can be further developed in IFPRI (and also in other CGIAR centers) to emphasize the relevance of direct action for food security through food-for-work, feeding programs, and a whole gamut of food-subsidy and -transfer programs. If this does not become a major thrust of CGIAR research (and its financing), the CGIAR will be justly seen, at best, as a minor partner, perhaps largely irrelevant, in the effort to lay to rest the specter of massive hunger as we see it in the world today.

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Just Faaland is emeritus fellow at the Chr. Michelsen Institute. He is currently chair of the WARDA Board of Trustees and a member of ISNAR's Board of Trustees. In 1990–92, he was director general of IFPRI and in 1982–85 was president of the OECD Development Centre. He has spent most of his professional life as an economist concerned with development, both as an academic and as an advisor and consultant in and for developing countries.

The Globalization of Agricultural Research: Subjective Reflections

Nasrat Fadda

A term that gains sudden popularity is often suspect. It raises the question of whether it describes a genuinely new product or is merely a repackaging of an already established commodity. In recent years this question has been raised in relation to, among other things, the concepts of sustainability, systems approaches, devolution, and ecoregionalism, and it is now undoubtedly relevant to the "globalization" of agricultural research.

There was a time when the international (should one say *global*) character of research was taken for granted. To a large degree, this was a by-product of an internal unity of global empires that facilitated the flow of information and the interchange of plant material and, above all, of personnel who could, and did, move freely within the imperial domains. They carried with them knowledge and expertise acquired in their former posts, which they meshed into the fabric of their work in the new setting. This process found expression in a culture of unhindered dissemination of the fruits of research and free access to them by scientists and others who found them relevant to their own work. Often, the interaction took place with amazing speed. One example of this is the pioneering work of Fischer and Micelle (1925) on the application of statistics to biological sciences, which had one of the earliest, perhaps *the* earliest, large-scale field application in 1927 at the Gezira Research Station, Sudan, in a classic experiment carried out jointly by E. M. Crowther of Rothamsted Experiment Station, UK; F. G. Gregory of the Imperial College of Science, University of London; and F. Crowther of the Research Division, Ministry of Agriculture, Sudan. Important in itself, this work laid a sound foundation for all future agricultural field experimentation in the Sudan.

At another level, the Cotton Research Corporation of the UK organized and coordinated an international cotton research network that linked together virtually all research, particularly variety testing, conducted on cotton in Asia, Africa, the Caribbean, and elsewhere. In support of this initiative it published a journal (*The Cotton Research Review*), which was an effective and widely read vehicle for reporting on all aspects of agricultural research carried out on cotton worldwide. The effort was maintained for several decades into the 1970s. By any standard, it was a truly global undertaking.

There are many other examples from the distant and recent past and from different countries. To dwell on them would only belabor the point. One, however, cannot leave out the living and most effective system for global research devised by the international community—the chain of international agricultural research centers associated with the Consultative Group on International Agricultural Research. Started some 50 years ago and substantially expanded in the last three decades under the sponsorship of the World Bank, FAO, and UNDP, this system has been the foremost standard bearer of the "globalization" of agricultural research. It has had impressive success in this role, exemplified in particular by the wide range of new, more productive, and widely adaptable crop varieties as well as the more advanced crop management practices it developed, its many contributions to the definition and understanding of problems and policies relating to national and international agriculture, and the valuable assistance it has given to national agricultural research systems. The record is well-documented in center reports and many other publications. In no small measure, the impact of the system, spearheaded by the new varieties of rice, wheat, maize, and other food crops and the production packages devised for their management, has been crucial to revolutionizing field-crop production in many a country. The benefits have not been confined to the developing world; some of the most agriculturally advanced countries have, indeed, been among the major beneficiaries.

If agricultural research has traditionally had a strong global dimension, why then is there this revived interest in "globalization" at this juncture? I believe that at the core of this concern is the changing character of agricultural research brought about by a burgeoning biotechnology revolution. More than ever before, recent developments in this field have introduced elements that lend themselves to commercialization, such as the ownership of varieties and genes, and the patenting of methodologies for gain. Commercialism is inherently restrictive to the use of the products of agricultural research. It apportions benefits by ability to pay rather than by need. Those concerned with the welfare of the less endowed countries and farming communities, recognize the need for measures to counteract the negative aspects of this emerging trend.

"Globalization" could be one of the routes to reaching this objective. The term carries with it a wider dimension than the mere curbing of excessive commercialization. While it is true that "globalization" is deeply rooted in the history of agricultural research, a restatement of the concept has other intrinsic advantages. In the first instance, it stimulates renewed interest in the subject, leading to a reassessment of its meaning and significance. It widens the boundaries within which it is to be understood and interpreted. By focusing attention, it should encourage a more active pursuit of its objectives and lend support to the programs and institutions that serve them.

Within this above context, any discussion of "globalization" would have to address a number of pertinent questions: Is it needed? Is it feasible? Is it implementable?

The desirability of "globalization"—of conducting research at one or a few specialized centers, linked with national systems, for the benefit of the world at large—rests on the commonality and applicability of many aspects of agricultural research to comparable ecologies and, not infrequently, to a wider range of conditions. This circumstance renders duplication unnecessary and wasteful of resources. Taxonomic work, the broad screening of agricultural chemicals, basic studies in biotechnology, and the development of methodologies, to mention but a few, are areas of research that can be effectively carried out at global centers and need not be duplicated everywhere.

Apart from the consideration of commonality, "globalization" is being dictated by the prohibitively high costs of certain types of research (e.g., gene mapping and genetic engineering), which put them beyond the reach of all but a few well-endowed countries, rendering them more suitable for cooperative efforts by global consortia. Interaction at this level would enhance the intellectual stimulation that is the essence of innovative research.

Granting that the "globalization" of all research would yield many worthwhile intellectual and economic returns, the question remains: Is it feasible? In the abstract, most things are feasible provided they are addressed with sufficient determination and allocated adequate resources. Agricultural research is no exception and, not withstanding its rising costs, much of it is, in fact, less demanding of resources than, say, certain industrial processes. A distinction, however, would have to be drawn between those areas of agricultural research that promise to have general applicability (broadly, pure or basic research and upstream applied research) and which can, therefore, be "globalized," and the site-dependent aspects that are properly the domain of national/ecoregional workers addressing problems of distinct situations (broadly, adaptive research). From this perspective, "globalization" is viewed not as a substitute for local effort, but as a valuable, enriching, and stimulating foundation for such research. The advance of global efforts calls for a parallel strengthening of national capacities to enable them to effectively monitor developments at the global scene, glean their most promising elements, test them under local conditions, and though extensionists, introduce them to the farming community.

The feasibility of "globalization" has been further enhanced by the communications revolution that has brought about an unprecedented fundamental transformation in the processes of scientific traffic and interaction. The reality of instant access to scientific literature and on-line contact among scientists through electronic means is now with us. It is already changing the ways in which scientists operate and has created a setting where they can work as global teams. The new opportunities have not yet been fully exploited, but their potential is, evidently, substantial. An active pursuit of "globalization" should help give substance to this potential.

Accepting the desirability, even the necessity, of "globalizing" important areas of agricultural research does not, by itself, ensure its automatic adoption. An essential requirement is an awareness by planners and funders in both donor and recipient countries of the long-term economies, scientific benefits, and increased agricultural production that can accrue from underwriting global initiatives. To be effective, commitments would have to be enduring and sheltered from uncertainties arising from ephemeral political moods. The most promising among the many proposals put forward to provide the required funding security, is, in my view, the creation of a buffer endowment fund of a size that would yield an income sufficient, at a minimum, to cover the uncertain proportion of likely future funding. The aim, the justification, and the fruits are clear. However, long experience raising sustained funding for institutions active in international agricultural research suggests that financial security is not likely to be easily attained. The objective, nevertheless, is worthy of rigorous pursuit.

In reflecting on a mechanism for "globalizing" agricultural research, one is reminded of the advice of a seasoned economist and planner working in Ethiopia some 30 years ago. On being questioned on how best to get development moving in the complex and extremely demanding situation then prevailing in that country, his simple reply was, "Look around to see where development has started and give it a push." Reference has been made earlier to the Consultative Group on International Agricultural Research and to the chain associated with it of international agricultural research centers with wholly or partly global mandates. This a ready system through which "globalization" can be given a push. It has a long, tested record of successful operation and has also proved flexible and capable of change. One of its main strengths has been its ability to forge strong linkages with both national and international agricultural research systems and networking with them and with others engaged in global, or potentially global, research. These are valuable foundations on which to construct future endeavors. An early need, however, is a review of existing patterns of cooperation with a view to a more explicit definition of the roles appropriate to the various partners in a rigorously pursued global research undertaking.

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About the Author

Born in Acre, Palestine, Nasrat Fadda received his higher education at the American University of Beirut, Lebanon, and the Imperial College of Science, London. For some 20 years, he served in various research posts in East and Central Africa, including the position of chief research officer in charge at the Kenana Research Station, Sudan, and FAO project manager at the Institute of Agricultural Research, Ethiopia. Between 1975 and 1988, he worked for the Arab Fund for Economic and Social Development, first as a senior agricultural officer, but mostly as the director of the Operations Department. In 1988, he returned to research as director general of ICARDA, a post he held until 1995. Currently, he is president of the Arab Development Society in Jericho, an agriculturally based welfare NGO.

The Globalization of Science: Agricultural Research in Developing Countries

William K. Gamble

Much has been written about the broad issues of the Globalization of Agricultural Research and the role of the International Agricultural Research Centers. This paper's comments are focussed on those National Agricultural Research Systems of developing countries that have not yet benefited greatly from "globalization and agricultural research."

Introduction

The globalization of science is a reality. However, many developing countries have had little success in adapting this body of knowledge into the various sub-units of their national research systems. In many of these countries, functioning communication systems (computers, access to the Internet, or even telephones) are still absent. In all too many developing countries, food production and the economy of the rural sector have shown little, if any, gain over the past decade.

Often, research is still focused on the generation of technology rather than on problem resolution, with an understanding of the economic consequences of the utilization of the technology. There is still much to be done in the areas of policy and political commitment, research scientist/client contact, population control, and reduction in poverty in the rural sector to enable developing countries to be active participants in the globalization of science.

The Globalization of Agricultural Research

The globalization of agricultural (including livestock) research first concentrated on the creation of "centers of excellence." These centers later formed the foundation of the Consultative Group on International Agricultural Research (CGIAR). By the 1970s, the CGIAR centers had moved from just being "centers of excellence" to becoming active partners in cooperative research and development activities with national agricultural research systems (NARS). Cooperative programs between NARS and CGIAR centers were often funded by third parties—typically donor governments and foundations. It was soon recognized that to achieve effective cooperation, many of the NARS would need to be strengthened. In many cases, the full participation of national systems was limited because of insufficient numbers of well-trained staff, organizational conflicts, and language and communication problems.

As a result, many donors entered into support programs to strengthen NARS through training, up-grading equipment and transportation, and reorganizing the system. Unfortunately, in recent years, donor support has almost disappeared for many developing countries, which have not supplied the essential resources to maintain and improve their own research systems.

Policy and Political Commitment

Many developing countries lack both a strong political commitment to agricultural development and the well-established agricultural policies required to support agricultural research and foster economic growth. In many of these countries, agricultural producers and processors are at an economic disadvantage compared to other sectors of the country's economy, as well as to the rural sector of other countries with more enlightened policies and political commitment.

In many developing countries the key issue in agricultural research policy has been self-sufficiency, although this has now more often than not been changed to food security. In many of these developing countries, concern for farm income simply does not enter into national policies. Often farmers are considered to have low incomes because they are "poor farmers" who are not willing to adopt new practices. In truth, however, farmers throughout Asia, Africa, and Latin America have always proven to be extremely good economists who allocate *available* resources wisely. The real problem is that the new practices often are not practical, given the resources available to many farmers.

This goes to the heart of the matter concerning policies and political commitment. The overriding government commitment is often for inexpensive food for the urban masses because that is the point of greatest political pressure. Pressure to increase farm incomes rarely carries such weight. This common lack of political commitment to adequate incentives for producers often results in production not keeping pace with demand. Governments then turn to subsidized imports for the urban population, and the problem grows even more complex.

Clearly, agricultural research systems need to provide their governments the information that policymakers need to set reliable agricultural development policies. Economists and other social scientists need to be an integral part of the research teams. Together, they must determine and present the necessary production and marketing information to the policymakers. An effort that is much stronger than what has been evident in many developing countries in recent years is required to determine and implement appropriate agricultural research and development policies—policies that will lead to improved well-being in the rural sector and which will also bring a sharper focus to research to solve high-priority problems.

Food security is always important, but to achieve food security, there must be a policy that provides incentives for profitable agricultural production. Many factors beyond product price or subsidies enter into the matrix, but too often they are not considered in setting agricultural policy. Some of the more important, and often ignored, factors include interest rates, land-tenure systems, transport cost and availability, market accessibility, labor cost and availability, tariffs, exchange rates, population growth, and the cost to maintain sustainability in agriculture.

Although the CGIAR centers and donors are making efforts to help developing countries address many of these issues of policy and political commitment, there needs to be a renewed and increased effort in many parts of the world. With many competing demands on governments, the needs of agriculture are often not heard loudly or clearly enough. The CGIAR centers and donors should focus greater attention on generating stronger political commitment to improved policies on agricultural research, development, and implementation in many developing countries.

The Research/Client Connection

Research/extension/farmer linkages vary from country to country. A great deal has been written about these linkages, and studies have been conducted to determine the most effective way to organize to maximize them. Most developing countries commit much larger resources to the transfer of technology (extension) than to problem-solving research.

To help insure that agricultural research is focused on problem resolution, greater contact is required between research scientists and their clients—producers, processors, supply companies, and policymakers—than now occurs in many countries. Traditional linkage systems still prevail in the majority of developing countries. These systems are set up so that the extension staff identifies problems at the farm level and interprets them to the research staff. The research staff then conducts the research to resolve the perceived problems and interprets the results to the extension staff. The extension staff then interprets the results to farmers. Much is lost in the communication process.

Several developing countries, with donor or loan support, have attempted to improve the communication process with the creation of adaptive research teams or adaptive research stations (operated by extension service staff). Observation of several of these efforts have indicated that these “teams” or “farms” have tended to become separate units with their own research agenda, with little reference either to research or extension. In a number of cases, these “adaptive” projects have been closed when external funding is terminated, but they remain a drain on limited resources because of the cost for upkeep for land, buildings, and underemployed staff.

There is a need to bring research scientists into much more direct communication with their clients. Comparisons can be drawn between research and development in agriculture and in business. In business, a "mission" is seen as a reactive strategy in which clients' requirements and expectations are met. "Vision," however, is seen as a proactive strategy designed not only to meet the clients' requirements and expectations, but also to anticipate their needs and gain their commitment and participation. Client-driven strategies require quality and service excellence at every level. In the process, clients are brought into every department of the organization, and their voices heard and acted on. Greater attention to *vision*, *quality,* and *excellence* is needed in agricultural research and the globalization of science. It is here that the CGIAR centers can play a key leadership role.

Food Security and Population

The elimination of hunger and malnutrition is not just a food problem, but rather, it goes to the heart of poverty and population growth. At the present time, many Asian countries are already overpopulated and in sub-Saharan Africa and many Latin American countries, development programs have been unable to keep pace with population growth.

The substantial growth in food production required to keep pace with expected population growth cannot be achieved without massive expenditures, unequaled in the past except in times of war. Nor can it be done quickly. Every effort must be made to produce more food more efficiently, developing systems of sustained yield, yet protecting the life-supporting resources of our planet. Such efforts, however, will be but a temporary stopgap unless we bring human population growth under better control. The world population today is about six billion and with present trends will reach about eight billion by the year 2025. Raising food output in the developing countries is essential, but so are the slowing of population growth and maintaining our ecological heritage.

Poverty

Much of international agricultural research, as far as it is concerned with poverty, has been directed at small farmers. These farmers often operate under unfavorable agricultural policies and a scarcity of resources. Today, more and more of those small farmers depend on off-farm employment for their livelihood. Governments need to do much more in the creation of employment in the nonfarm sector. This goes back to the issues of policy and political commitment.

Poverty cannot be solved by agriculture; it is a complex problem that includes all aspects of society and the economy.

Concluding Statements

Much has been accomplished in the last 50 years. Much still needs to be done. While there has been globalization in a macro sense, there are huge gaps in many national programs. An international communication network exists for those with the tools to access it. But many research and development systems lack a single operating computer. Many are unable to fund current scientific journals. Many have massive amounts of essential scientific equipment that is inoperative because of a lack of parts and maintenance. Many countries have vast numbers of underemployed extension staff. Many lack sufficient funds to buy petrol so scientists can visit off-station experiments. And many of the developing countries have bureaucratic systems and procedures that prevent research scientists from direct contact with farmers.

There is a need for substantial support from the industrialized nations to assist developing nations in their agricultural research and in the reduction of poverty through the creation of employment opportunities. There is also a great need to slow world population growth through acceptable means.

Finally, there must be an increased focus on the importance of appropriate agricultural policies and political commitment by many of the developing countries. The policies must be based upon solid research that has demonstrated its economic benefits to clients, taking into account their available resources. Also, based upon research conducted in cooperation with the clients, the policies must be socially and culturally acceptable. The CGIAR centers and the international donor community have shown a great deal of leadership on these matters but they can, and should, continue to play an active role in this effort.

About the Author

William K. Gamble served as director general of the International Institute of Tropical Agriculture (IITA) from 1975–1980 and founding director general of the International Service for National Agricultural Research (ISNAR) from 1980 until his retirement in 1985. Prior to 1975, he served in the Ford Foundation's agricultural research and development programs in Asia, Africa, and Latin America. Gamble holds BSc and MSc degrees from Iowa State University and a PhD from Cornell University.

Some Issues and Priorities for the CGIAR in Global Agricultural Research

E. H. Hartmans

One of the key problems of the world today is hunger, malnutrition, and rural poverty. At this moment in time—also as a result of the forthcoming World Food Summit—attention is focused on the universal eradication of hunger as well as the achievement of an adequate standard of living, including safe and nutritious food for all humankind. As access to food is considered a basic human right, food security must therefore be fundamental to development policy for all nations.

Introduction

The important role that agricultural research has to play in this context is accepted by everyone. To what extent the CGIAR system can contribute to providing the necessary means for attaining this fundamental global objective and what role it should play in the future will, I trust, ensue from some proposals I will make in this paper. My observations are based on my own experience as director general of IITA and my subsequent involvement in international agricultural development and emergency relief work.

The CGIAR is the only structured global agricultural research system with no strong dependence on national and international authorities. Therefore, more than any other organization, it is in a position to deal objectively with the present urgent agricultural problem, i.e., "safe and nutritious food as a basic human right to all."

After the initial dramatic results achieved by IRRI and CIMMYT on rice, wheat, and barley, which greatly influenced the structure and research course of action of the CGIAR system, it was assumed and argued that a commodity or product approach, with a concentration of high-level scientists and abundant financial resources, could give similar results with other crops in given geographical areas. Although significant research results were obtained in various fields, their impact at national levels were rather disappointing. It was therefore decided to give more attention to socioeconomic matters as well as to national research programs, leading to the creation of IFPRI and ISNAR.

In spite of this evolution and of the creation of other centers specializing in livestock, agroforestry and forestry, irrigation management, and plant genetic resources, the CGIAR in the last decade seems to be losing its great appeal and, consequently, its financial support from the international community.

No doubt the fast growth of the system through the creation of new research centers or the inclusion of existing ones has put heavy pressure an the financial resources available for each center during a period when many donor countries are also trying to make substantial cuts in their budgets.

The very high priority originally accorded to the CGIAR core budget has diminished. And this is in spite of the fact that donor countries still have large financial resources available for development aid, in comparison to which the total budget of the CGIAR is a relatively small amount. The money is used for other bilateral or nongovernmental purposes in both research and development. *Why* are the donor countries acting this way instead of meeting the urgent needs of the well-conceived budgets of the centers? The question becomes even more significant when this is done despite the unanimous recommendations made by the member states of the European Union to *reinforce and broaden research on food systems with an emphasis on sustainable management of natural resources and equity* (made at the Intersession Working Group of the Committee on Food Security, held between 29 July and 2 August 1996 at FAO headquarters in Rome).

In soliciting the international and scientific communities to strengthen their agricultural research, these member states advocated that such programs should focus on *interdisciplinary research* to provide a basis for policies and action to maintain natural resources while increasing the production potential of agriculture, forestry, and fisheries.

Among other things, the European countries further urged their member states to participate and support international cooperation in research to *promote food security*, with special emphasis on *underutilized crops*, thereby strengthening the links between CGIAR centers and the United Nations and other international research bodies. They also asked governments to ensure the institutional framework to allow the *full participation of all interested parties, including local people and farmers' and fishers' organizations in the identification of research needs, and to ensure that suitable systems of dissemination and extension of research results are in place*.

At the Madras Science Academy Summit (held between 8 and 11 July 1996 at Madras, India) it was agreed that "never before has science offered a greater opportunity to achieve the goal of universal eradication of hunger . . ." and that "innovations emerging from the fields of biotechnology and information technology, from management systems in soils, health care, common water use, integrated pest management, and integrated intensive farming systems represent only a few of the opportunities to reach the 800 million people lacking adequate nutrition.

"However, tapping the potential depends on strengthening the capacity of national and international agricultural research and development systems in order to respond to these new challenges with creativity."

The answer for the decline in the support for the CGIAR lies in these preceding paragraphs and, at the same time, provides an indication how the CGIAR can shape its future course of action in the next 10 to 15 years.

It is my opinion that for too long the system has been

- too product or commodity oriented rather than focused on major international problems such as food security, conservation of resources, and the environment;
- too inward looking and isolated rather than integrated and interlinked in research and action programs with national research and development systems and national nongovernmental agricultural organizations.

In this paper, I wish to elaborate briefly, on these two issues, which must be redressed if the CGIAR is to meet its primary objective: i.e., to be an effective global agricultural research and development system.

Problem Orientation

The major obstacles to a healthy and productive life are primarily due to human factors, such as ethnic strife, misallocation and mismanagement of resources, lack of access to land and the means of production, unbalanced increases in population, lack of information on production potentials, and misdirected national and international policies.

Apart from these problems, there are the problems of natural disasters, among which the most important are droughts, floods, and epidemics of pests.

To what extent have these major problems been given serious consideration in shaping the programs of the CGIAR system? Apart from such issues as drought resistance in crops, flood control, and pest control in plants and animals, which have been taken on by concerned centers, these matters have never been considered or tackled on an organization-wide, coordinated basis. This, in my opinion, must be done.

I am therefore suggesting that a *Special Working Group*, with members from both inside and outside the CG system, be established to examine what role the CGIAR, in collaboration with other organizations, can play in dealing with both manmade problems and natural disasters. Which are the major causes of hunger and malnutrition? This may well lead to a much closer integration of activities among the presently rather independent centers. In fact, wherever collaboration presently exists between centers, it has been almost entirely the result of personal initiatives between the directors and respective boards of the centers. A closer integration of activities between centers will undoubtedly have consequences for the whole organizational and management structure of the CGIAR.

Integration with National Research (NARS) and Development Organizations

The CG centers, except for IFPRI and ISNAR, have carried out their research activities primarily in their own headquarters and in their substations in fairly great isolation. Even at the subregional stations, very little contact in the programming and execution of research projects exists with local research or other governmental and nongovernmental organizations.

As a consequence, the NARS have considered the centers as entities with a task outside their own work. This situation has sometimes led to poor human relationships and misallocation, as well as misuse, of resources at both national and international levels. Some steps have been taken in the recent past to correct this situation by establishing additional substations and setting up networks for various commodities and research activities in conjunction with holding workshops and seminars. While such activities are welcome, they are far from enough. Further initiatives must be taken so that the NARS see their activities as an integral and integrative part of the programs of the centers.

At present, considerable resources are often spent by the NARS in staffing and finances, basically duplicating or second-guessing the activities of the centers. This is a considerable waste of resources and is particularly serious, since resources allocated to national research programs are already very limited in developing countries.

From a conceptional point of view, the centers should be responsible for basic research activities that diagnose and deal with key problems in agriculture, forestry, and fisheries. For this work, a great capacity in scientific human and financial resources is normally required. The NARS, in turn, should develop their specific action-oriented research and development activities in close collaboration with center scientists.

ISNAR could well play a major role in bringing about this complete integration of centers and national activities, so that the centers are considered a basic part of the NARS and the NARS, a basic part of the centers.

In this context, the strict separation of research and development in the CGIAR should be reexamined. With the greater integration in national programs, much greater participation may be desirable in on-farm research and in training and development projects. One example of this is participation in demonstrating new technologies in field days and training of farmers. How the centers could be cooperating with or setting up efficient extension systems in their areas of influence should therefore be taken into serious examination.

The Special Working Group proposed in this paper should also examine the future role of the centers, and the system as a whole, in relationship to national and development organizations. Full consideration should be given to new information and communication tools such as the Internet and GIS mapping, as well as to the role of nongovernmental organizations, in order to make the most effective use of available resources and tools for development.

This new orientation of the IARCs would undoubtedly lead to better use and dissemination of research results. It would furthermore strengthen the centers' impact in their areas of intervention, give them a more impressive image as far as donor countries are concerned, and eventually contribute to the decrease of hunger, malnutrition, and rural poverty in the world.

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About the Author

E. H. Hartmans started working in the field of agricultural economics in 1950 in the Netherlands, having earned his PhD from Michigan State University that same year. He worked at FAO from 1959 to 1980, serving in many different capacities, including director of the Agricultural Services Division, of the Agricultural Planning Division, and of the Field Programme Division. From 1980 to 1985 he was director general of the International Institute of Tropical Agriculture in Ibadan, Nigeria. In 1986 he was awarded the Doctorate in Science Honoris Causa from the University of Lagos, Nigeria.

Agriculture in the 21st Century: A New Global Order for Research

H. K. Jain

Beginning with the first quarter of the 21st century, agriculture will take a new direction. It will have to be more productive, transcending emerging yield ceilings, and this greater productivity will have to be combined with sustainability and the conservation of natural resources. The production process will also have to be highly efficient in terms of energy input-output ratios. It will derive much greater support from renewable resources of energy, based on continuing advances in molecular biology and microchip-based sensors, reaching out in this way to millions of small and marginal farmers in stressed environments.

Introduction

When the history of development assistance in the 20th century comes to be written, some contributions will stand out for the highly visible nature of their impact. One such contribution is the Green Revolution technology developed by the international agricultural research centers like CIMMYT and IRRI, working in collaboration with the national agricultural research systems of the developing countries. The high-yield technology of wheat and rice generated through these collaborative efforts is believed to have saved millions of people from starvation. The vision that made this possible was provided by men like George Harrar, Forrest Hill, Sterling Wortman, Robert McNamara, and political leaders like C. Subramanian.

A new vision and greater statesmanship will be needed for widening the scientific basis of agriculture in the 21st century to give it a new direction. Our present technology of agricultural production, good as it is, had its course determined not so much by scientific considerations alone as by two major developments, which had a decisive effect. First, the discovery of vast fields of fossil fuels in the Middle East in the early part of this century shifted the focus to nonrenewable resources of energy and ignored considerations of efficiency and environment. Second, the desperate food shortages that many developing countries faced in the 1960s and 1970s with rapid population growth left little option except to seek shortcuts to increased production in order to buy time for new approaches later. This strategy has paid rich dividends and, despite criticism from some social scientists, the fact remains that it helped to avert large-scale famines and starvation.

The Challenge of the 21st Century

The 21st century must seek new solutions and call for greater global collaboration and cooperative efforts if agricultural research is to meet new challenges. Nothing short of a new world order for agricultural research will be needed. What will some of these challenges be and what are some of the forces that will drive agricultural research as we enter the next century?

Unrelenting population pressures

The need for new and more productive technologies will arise from the fact that the population pressures in many developing countries will continue to build up. The countries most at risk are those of sub-Saharan Africa, with the highest population growth rates, and those of South Asia, where a large part of the developing-country population lives at present. A World Food Council paper on Africa, produced jointly by IFPRI and ISNAR, concluded that the countries of the region would have a food production gap of 50 million metric tons at the end of the century and an inconceivable deficit of 245 million metric tons by the year 2020, assuming a growth rate of only 2 percent in food production and constant 1980 human fertility. These projections already appear to be overly pessimistic, considering the progress that many countries of sub-Saharan Africa have made in the past five years. But the problem remains serious. India, where the Green Revolution technology made a particularly impressive impact, finds that it must continue to add 6–7 million metric tons to its annual production of food grains until the end of the century and thereafter maintain an even higher growth rate consistent with continuing population build up.

However, the growth rate in food production in more recent years shows signs of stagnation. A recent World Watch Institute report compared food and population projections for the next 40 years with the trends of the last 40 years. Between 1950 and 1990, the world added 2.8 billion people, an average of 70 million a year. But between 1990 and 2030, the projected global increase is 3.6 billion, or 90 million a year. The world added 1.15 billion metric tons of food grains between 1950 and 1990, but with present trends, the next four decades will see an addition of only 369 million metric tons. Thus, while the annual increase from 1960 to 1984 was 30 million metric tons, between 1984 and 1992 it dropped to 12 million metric tons. These projections clearly underline the need for a massive effort in science and technology to help achieve another breakthrough in the production of food grains.

The increased demand for food grains and other agricultural commodities are not merely a function of continued population growth. The demand also arises from the fact that with economic growth, people in developing countries will be consuming more food of animal origin, leading to the plant-animal-human food chain that has already become standard practice in the developed countries, even though there is little evidence to show that this is based on recommended nutritional requirements. While the yearly consumption of food grains in many developing countries is 200–300 kg per person, the corresponding quantity in many of the industrialized countries is 400 to 800 kg per person. A large part of this quantity is fed to animals for the production of meat and other products, and since animals are not good convertors of food grains into meat, the efficiency of this food chain is quite low.

Sustainability of production systems

Perhaps the most important consideration in the planning of agricultural research for the next 25 years will be the need for a much greater focus on the sustainability of high-yield production systems. The present agricultural technology associated with the Green Revolution is based on a simple paradigm of favorable genotype-environment interactions. Plant breeders develop crop varieties that are genetically well equipped to take advantage of heavy doses of modern farm inputs like inorganic fertilizers, pesticides, irrigation, and farm machines. The modern varieties of crop plants thrive in a highly manipulated agronomic environment dominated by the use of chemicals of various kinds, derived in many cases from fossil fuels. There are serious concerns about the long-term viability of some of these technologies.

These concerns arise from the fact that with the development of irrigation, vast tracts of agricultural lands have been lost to crop productivity because of increasing salinity associated with water logging. Also, there has been large-scale mining of lands, leading to deficiencies of plant nutrients like zinc and copper. The wheat-rice rotation that in recent years has become the fundamental basis of food security in much of South Asia continues to present serious problems of long-term sustainability. Some of the high-yielding varieties no longer show the kind of productivity they did in earlier years. Scientists at IRRI have observed that some of their modern varieties show a declining trend in yield, even with high input use. There is no reason to believe that their genetic potential for productivity has deteriorated, but apparently soil conditions following intensive cropping over a number of years no longer provide the kind of favorable conditions for crop growth they did in earlier years.

The Technical Advisory Committee of the CGIAR has defined *sustainable agriculture* as a process that over the long term, enhances environmental quality and the resource base upon which agriculture depends, provides for basic human food and fibre needs, is economically viable, and enhances the quality of life for farmers and society as a whole. This definition of sustainable agriculture is consistent with the statements made in the Report entitled “Our Common Future” produced by the World Commission on Environment and Development constituted by the United Nations. Also known as the Bruntland Commission, the commission defined sustainable development as new paths of progress that meet the needs and aspirations of the present generation without compromising the ability of future generations to meet their own needs.

This concept of sustainable agricultural development is realistic, even if one could argue that it suggests a certain arrogance on the part of humankind. We seem to be saying that we have every right to increase our population as much as we like even though the need for high birth rates is no longer justified because of greatly reduced child mortality. And our food habits will continue to be determined not by scientific considerations of what constitutes balanced nutrition, but by our cultural preferences. Humans are the only species that makes such unreasonable demands on nature and natural resources.

Environmental and Efficiency Concerns

The intensive use of chemicals in modern agriculture is also responsible for major environmental concerns, starting with the publication of the book *Silent Spring.* There has been a build up of nitrates in our rivers and lakes, which are the sources of our drinking-water supply. There are other environmental ill-effects, such as the contamination of foodstuffs with residues of pesticides and toxic chemicals.

The evolution of this kind of technology started during a period when fossil fuels were cheap, abundant, and readily available, and energy was not a major constraint. No one was seriously concerned in the early years of this century with the efficiency of the agricultural production process. Few estimates were made of the energy input/output ratio in different systems of agricultural production. It is only now, following the oil crisis of the 1970s and increasing recognition of the adverse impact of the use of chemicals on the environment, that scientists are beginning to focus on the issue of efficiency. The close correlation between cereal output per hectare and per agricultural worker with commercial energy use can be seen in table 1. Western Europe uses the largest amount of energy in its agriculture, followed by North America, with Africa using the least. So great is the dependence of modern agriculture on investments in commercial energy that some critics have described it as a convertor of fossil fuels into edible biomass.

One response to this concern about the environment has been a call that world agriculture should revert to its traditional methods with major emphasis on recycling of organic wastes and residues for meeting the nutrient needs of crop plants. This option, however, no longer exists. The traditional systems of farming with all of their professed virtues are based fundamentally on low crop yields. They were a compromise between low yields and small human populations, kept in check by disease epidemics. All this has changed—and in the last 30 years. More than ever before, the need now is to increase productivity per unit of land, and all possible resources of modern science must be harnessed to achieve this objective. The solutions to our emerging problems will not be found in low-input agriculture.

The question we must ask is whether the scientific basis of agriculture could

Table 1. Commercial energy use and cereal output per hectare and per agricultural worker, 1972

Region	Energy per hectare (10^9 joules)	Energy per worker (10^9 joules)	Output per hectare (kilograms)	Output per worker (kilograms)
Developed countries	24.8	107.8	3,100	10,508
North America	20.2	555.8	3,457	67,882
Western Europe	27.9	82.4	3,163	5,772
Oceana	10.8	246.8	976	20,746
Other developed countries	19.4	19.1	2,631	2,215
Developing countries	2.2	2.2	1,255	877
Africa	0.8	0.8	829	538
Latin America	4.2	8.6	1,440	1,856
Near East	3.8	4.4	1,335	1,386
Far East	1.7	1.4	1,328	781
Centrally planned economies	5.9	6.8	1,744	1,518
Asia	2.4	1.7	1,815	911
Eastern Europe/USSR	9.3	28.5	1,682	4,109
World	7.9	9.9	1,821	1,671

Source: Stout, B.A. 1982. Energy for World Agriculture. In *Energy Management and Agriculture*. Royal Dublin Society.

be further enlarged so as to make it both highly productive and efficient in terms of the energy input-output ratio. The scientific advances in molecular biology should make it possible to substitute many nonrenewable resources of energy with those of a renewable kind, such as biologically fixed nitrogen and control of insect pests through biological means. The agriculture of the 21st century for which we must begin preparing now should find answers by invoking major advances in science rather than going back to traditional technologies.

Production, equity, and management of natural resources

An impression exists in the minds of some people that research on management of natural resources should receive greater attention because of the concern for environment and future generations. In reality, the problem is more urgent. The food needs of people in large parts of the developing world can not be met in the next 25 years unless the problems of degraded lands and damaged soils are addressed and a new kind of production technology developed for the vast arid and semi-arid regions.

It is true that the full production potential of the high-yielding varieties of wheat, rice, and other crops developed in the past 30 years has not been fully exploited in many developing countries. This unutilized potential remains an important source of increased food production. However, realizing this potential is not going to be easy. Farmers in many of these countries have already exploited the more comfortable part of the response curve of the new varieties. They will now be required to move into the more difficult part of the curve, which would call for applications of higher doses of chemical fertilizers and other inputs, with diminishing returns.

The scientific challenge will be the generation of a new kind of production technology for the vast dry and marginal lands, which so far have received relatively little attention. It is known that the key to improving the productivity of these lands lies in the rehabilitation and restoration of their soil fertility and in the conservation and management of rain water so that enough moisture is available to provide the equivalent of one or two protective irrigations. *Efficient rainwater management would be the single most important factor in improving the productivity of these lands, many of which receive significant amounts of precipitation during the year.* Once enough of this water is conserved to sustain some of the critical stages of crop growth, the high-yielding varieties already developed could be introduced with the application of moderate doses of chemical fertilizers.

Many developing countries are currently grappling with the process of economic reforms and structural adjustment. In this context, they recognize the need to provide an income safety net for the poor before the trickle-down impact of economic growth begins to be felt. Scientific transformation of agriculture in low-fertility lands and in the more difficult agroecological situations could become the most important component of such a safety net. This would be a process of economic empowerment of the rural poor that should go hand in hand with the programs of structural adjustment.

New Paradigms for International Agricultural Research

If agriculture in the first quarter of the 21st century is to be more productive, if it is to transcend the emerging yield ceilings—combined with sustainability and greater efficiency—and derive major support from renewable resources of energy, and if the new technology has to reach out to millions of small and marginal farmers in stressed environments, new paradigms of international cooperation and linkages will have to be explored.

In the second half of this century, when many developing countries were faced with serious food shortages, with their own research institutions hardly equipped to lead the drive for the transformation of their traditional agriculture, leaders of the Rockefeller and Ford Foundations took the bold initiative to help create the IARCs, a concept which they later sold to the World Bank, UNDP, FAO, and the donor community in general. This new concept turned the theory of development assistance on its head; the conventional wisdom had been that donor assistance is best provided by transferring technical skills and resources to developing countries, but in the end, they must do the job themselves. George Harrar and Forrest Hill, among others, appeared to be saying that this was all very well but how do you make sure that millions of people will not die of starvation during the years the developing countries took to formulate new research policies and create the needed institutional framework for a more modern agriculture? In retrospect, their bold experiment succeeded beyond all expectations.

The need in the next 25 years will be of a different sort, as discussed above, but once again people of vision and political leaders not restricted to narrow considerations of traditional foreign policy will be needed.

It was understood though never clearly spelled out that the international centers would substitute for the weak national institutions and would do the more advanced technology-generating research. They would pass on the products of their research to scientists in the national programs for testing and adaptive research under local conditions before the new technologies were recommended to farmers.

The national institutions were clearly treated as junior partners, but few questioned the lead role of the international centers at that time. The national research managers were looking for support, recognizing that their own scientific and other resources were very limited.

Emergence of a Global System

If the objectives will now be different, as stated above, many of the IARCs, as planned originally, will not be able to provide the solutions. Nor will any other group of centers with highly centralized research programs of their own.

The essence of the globalization of agricultural research in pursuit of these objectives will be new forms of partnerships and joint programs between a wide range of research institutions of different countries—developed and developing—in the tropic, subtropic, and temperate regions. The collaborating NARS, as broadly defined, will include not only the government-funded research institutes of the ministries of agriculture, science, and education but a large number of other partners, including those in the private sector, the universities, and other institutions of higher learning and research (e.g., the Rockefeller Institute) and the international scientific unions of ICSU.

In addition, there will be a new kind of IARC whose primary function would be to facilitate linkages and partnerships between research institutions of different countries and to be a focal point for identifying priority areas of research where cooperative regional and global programs would be most useful. They will also provide catalytic support for fostering such partnerships and they will have a coordinating function.

This kind of broad-based partnership and emerging globalization of research may be illustrated with a few examples.

Plant breeding

The CG system in its heyday was described as the largest plant-breeding enterprise. It still is. However, with the signing of the GATT agreement by most countries providing for *sui generis* intellectual property protection in the form of plant-breeder rights, there will be considerable incentive for national and transnational seed companies to increase their investment in research on plant breeding. There would be no reason why the next generation of maize hybrids developed in the USA should not find their way into India through the local research subsidiaries of the companies developing the seed. Similarly, India, which has one of the world's largest labor pools in the field of crop breeding, could export its expertise to a large number of neighboring countries and beyond, where they would be protected under the provisions of the GATT agreement. A good example of the new partnerships that should emerge is provided by the Wageningen Agricultural University in the Netherlands, whose research institutes undertake a great deal of strategic research in close collaboration with private-sector seed companies, which in turn, have subsidiaries in many developing countries. Collaboration of this kind will multiply, involving research institutes, universities, and the private sector in many countries.

Efficiency of the production process

The National Academy of Sciences in Washington, DC, organized a Committee on Agricultural Production Efficiency in 1971. The Royal Dublin Society similarly debated some of these issues in the course of an international seminar. However, the short-term considerations of increasing food production have continued to prevail, and there has not been much focused attention on enriching the scientific basis of agriculture in order to make it more efficient, taking into consideration the long-term needs of humankind. Recent advances in molecular biology and microchip technology offer opportunities for a new scientific transformation of agriculture, but most studies of this kind have remained isolated. The need in the next century will be to organize a coordinated and focused approach around selected priority themes, e.g., photosynthetic efficiency. ICSU, representing the scientific academies of different countries, could play a major role in this effort.

Resource management research

Some people would argue that the IARCs have no comparative advantage to take up research on resource management with a high degree of location specificity. It is widely believed that the past success of the CG centers is in large measure due to the fact that the improved germplasm could be readily moved from a centralized location to different parts of the world for testing and adaptive research. This may be true, but the fact remains that international cooperation is needed to tackle some of the complex and intractable problems that the national institutions cannot solve on their own.

The notion that new technologies for more efficient management of natural resources could not be widely disseminated is probably not as valid as many people think. Some of these technologies should be quite transferable and could have a significant impact, similar to that of the high-yielding varieties. A good example is provided by the work done in Israel in the field of water management, e.g., the drip irrigation technology. Cooperative research programs between Israel and many developing countries could have a tremendous impact on world agriculture. International centers would be called upon to assist in fostering such collaboration.

New international centers like ICRAF, ICLARM, and IIMI have been added to the CG system in recognition of their professed commitment to research on the management of resources. These centers and others, like IBSRAM, will obviously find a very important place in the new global system of agricultural research. They will have to be strengthened and asked to provide the kind of leadership that CIMMYT and IRRI had in earlier years. Their present low-key approach is not consistent with the important contributions expected of them. Some of the other CG centers could be transformed to perform the coordinating and facilitating functions discussed above.

Biotechnology

The argument advanced in the 1960s—that it would take many years for the developing countries to create the needed institutional framework for research—still holds as far as biotechnology is concerned. The problem lies with the teaching of biological sciences in the universities of developing countries. This has not changed much with the emergence of new biology and the rise of biotechnology since the 1950s. UNESCO should have a major role in helping these universities to reorganize their courses and in equipping them for the new courses. UNESCO's preoccupation with a new international information order may be justified, but in the short term, it can make a major contribution by assuming leadership in fields like the teaching of biological sciences.

A large part of the current research in biotechnology is being carried out at present by scientists employed in the private sector in industrialized countries. Also, much of this new technology is protected by industrial patents under the new regime of IPR. Developing countries would need support from research institutions and universities in the public sector of the developed countries in setting up their biotechnology training and research programs. Some of the CG centers, like ILRAD (now merged with ILCA to form ILRI), are already heavily involved in biotechnology research. With some reorganization, they would have an important contribution to make in the next 25 years.

Plant genetic resources

Nowhere will the need for international cooperation be greater than in the conservation and exchange of plant genetic resources. Intellectual property protection in the form of patents for plant varieties and the Biodiversity Convention have been retrogressive steps in the development of world agriculture. The restrictions imposed by the Biodiversity Convention could apply to microorganism and wild species of plants in the forests, but as far as any exchange of seeds and planting materials is concerned, the open-door policy should continue, subject to plant breeders' rights as provided in the GATT agreement. UPOV, the Geneva based International Union for Protection of Plant Varieties, which currently coordinates the implementation of plan- breeder rights, should be reorganized to become truly international in its character. Its focus should shift from purely commercial considerations to a long-term vision for the management of plant genetic resources in the best interests of the growth of world agriculture as it enters the 21st century.

Creating New Genetic Potentials for Productivity

Impressive progress has been made, especially in the last 30 years, in creating a high genetic potential for crop yields. However, in crops like wheat and rice—the food staples of much of the world—yield ceilings are beginning to emerge. Most of the yield increases in these and other crops have come from a redistribution of photosynthates so that more dry matter is recovered in the form of grain. There is a limit, however, to such redistribution, and the challenge now would be to manipulate the rates of photosynthesis. ICSU, with its membership of powerful scientific visions and national science academies with some of the best brains in basic research, could provide much-needed leadership for research of this kind. The needed institutions already exist. Agricultural scientists will have to seek collaboration with them and build tighter linkages.

These are but a few examples of the diverse partnerships and linkages that will be increasingly developed as agriculture takes a new direction in the 21st century. Neither the NARS nor the IARCs will stay in their present form. Both, however, will have important contributions to make but they will need a new vision and a different way of doing business. They will have to involve a much larger number of partners, and the distinction between the public and private sector will become blurred.

About the Author

H. K. Jain is a former director of the Indian Agricultural Research Institute (IARI). In the early 1980s, he planned, organized, and managed one of India's largest research programs in agriculture. Earlier, in the 1970s, as chief of the genetics division of the institute, he helped to diversify its development projects on high-yielding varieties. He proposed the concept of a multilineal complex of genetically diverse cultivars distributed in space and time to contain the threat of disease epidemics. During his leadership, the institute became the coordination center of a large number of national programs, spread over a large number of research centers in the country. He also headed the country's largest graduate school in agriculture, which has produced several thousand PhD and MSc graduates in the past 40 years. In 1984, *Dr. Jain moved to ISNAR as deputy director general, where he supervised the center's advisory service program, which developed collaboration with more than 40 countries.*

Dr.Jain obtained his PhD degree in cytogenetics from the University of Wales in 1956 and his early work at IARI resulted in a series of papers on the chromosomal mechanisms of genetic recombination, for which he received several scientific awards and was elected a fellow of the Indian National Science Academy. He has been a member of the board of trustees of CIMMYT and IBPGR and of the Policy Research Council of ACIAR. Now back in New Delhi, Dr. Jain continues to write on agricultural research policy and chairs several committees.

Widening Circles of Research Collaboration for Greater Food Security

Emil Q. Javier

F*ood security* implies access by all people at all times to enough food for an active, healthy life (Reutlinger 1987). Although increased food production at the national and global level is necessary for food security, it does not in itself guarantee food security to all segments of the population. Famine and hunger in developing countries often result from a lack of access or lack of entitlements to food by poor people (Sen 1981). Although a sufficient supply of food may be available at the national level, a segment of the population may not have the capacity to acquire it because of a lack of purchasing power.

Introduction

Continuing, albeit slowing, population growth in many developing countries adds to the growing number of people unable to meet their basic food needs. The Asian population is expected to increase by 18 percent during the 1990s and by 53 percent in the next 30 years (UN 1992). In South Asia alone, where unmet demand for food is still large, the, population will grow by another 800 million people over the next 35 years. The challenge to the agricultural research community for improving food security is to produce more food for a growing population in an environmentally sustainable way and make it more accessible to the poor.

In addition to food production, a comprehensive approach to food security must take into account employment generation for the rural and urban poor, population planning and moderation, and a system of entitlements for the truly poor. A lasting solution to the problems of food security would require new development paradigms, new research approaches and collaborative arrangements, and novel partnerships.

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Modern Technology, Food Production, and Food Security

The nexus of modern technology, food production, and food security may be described in terms of the environments in which food is grown. On the one hand are the relatively benign agricultural environments with fertile soils, favorable regimes of water and temperature, and access to inputs and infrastructure, from which the bulk of food comes. On the other hand are the less favored and fragile environments where most of the "food-insecure" producers live. Facing the challenge of food security does not imply a choice between favorable and unfavorable environments; rather, it requires us to seek sustainable productivity growth from both.

Sustaining Green Revolution productivity gains

The impressive success of Green Revolution technology for rice and wheat, in increasing food production, has been well documented (Anderson, Herdt, and Scobie 1985). Green Revolution technology, based on a combination of high-yielding varieties, irrigation, fertilizer and other complementary inputs, was rapidly adopted in areas with access to these inputs. The improved technology was embedded in seed and, hence, was easier to transfer and adopt. The relative homogeneity of the favorable environments made widespread adoption of modern varieties possible.

The Green Revolution contributed to achieving food security mainly by inducing a long-term decline in the real price of food grains. Poor consumers, both urban as well as rural, who spend a major proportion of their income on food, were able to afford more of the cheaper food. In addition, intensified use of favorable lands resulted in an increase in the demand for labor and thereby helped increase labor incomes in unfavorable areas through seasonal migration (David and Otsuka 1994).

Despite an impressive growth in yield of food grains, in the wake of the Green Revolution, recent trends indicate that the productivity growth is slowing down. For example, the growth rate in rice yields in Asia declined from 2.6 percent in the 1970s to 1.5 percent between 1981 and 1988 (Hossain and Fischer 1995). Long-term experiments at IRRI indicate that rice yields and total-factor productivity of rice in many irrigated areas are either stagnant or have declined over time (Cassman and Pingali 1995). Opportunities for exploiting the yield gap have also narrowed, as "best" farmers' yields in intensive systems have approximated the yields at research stations (Pingali 1994).

In addition to declines in yield and total-factor productivity, most likely caused by a host of soil-related factors (Cassman and Pingali 1995), several other changes are making it difficult to maintain yield gains in the favorable environments. Deterioration of irrigation infrastructures, increased demand for water by industrial and urban sectors, conversion of productive irrigated land to nonfarm uses, increased cost of production due to the need to apply more inputs, increased cost of inputs, and environmental and health concerns associated with intensive agricultural production are some of these factors.

Sustaining productivity gains in the favorable environments while minimizing adverse environmental effects would require substantial improvements in the efficiency of input use. Efficiency gains can be achieved through technologies such as integrated pest management, biological control, improved nutrient management, and judicious use of irrigation water. Efficiency-enhancing technologies are generally knowledge intensive and provide more modest economic benefits compared to the dramatic gains from the seed-fertilizer technology of the Green Revolution (Byerlee 1993). These technologies are also highly site specific and require a significant level of farmer time in learning and supervision; their adoption depends on input savings relative to the cost of time spent in acquiring and processing improved technical information.

In addition to research on maintaining yield gains, continuing efforts need to be made to push the yield frontier higher by applying modern science to varietal improvement. Exploitation of hybrid vigor, apomixis, and the use of biotechnology for identifying genes and widely transferring genetic materials are some of the avenues offered by modern science. Plant breeders and physiologists have also been able to develop a “new plant” rice ideotype with a higher harvest index.

Enhancing productivity in unfavorable production environments

Agricultural producers in the unfavorable environments, rainfed lowlands and uplands, have been generally by-passed by the Green Revolution, both in terms of the suitability of modern technology to their environments and in terms of policy support, especially in the provision of infrastructure and support services. Unfavorable environments are often fragile, heterogeneous, inaccessible, and inhabited by the poor and the minority (Jodha 1992). Enhancing food security for populations in the unfavorable environments is a continuing and often elusive goal for agricultural scientists and policymakers. Our record in finding effective solutions to the poverty problems in the unfavorable environments has been poor. There are several reasons for this lack of success:

- The heterogeneity of the rainfed environments makes it difficult to exploit the economies of size in varietal improvement as has been done in irrigated environments.
- Poor soil fertility and, in sloping areas, high susceptibility to erosion, constrains intensive production of food crops.
- The predominance of abiotic stresses, especially drought and/or submergence, makes investments in intensification very risky.
- Poor infrastructure for transport and marketing discourages the movement of food out of low-yield, subsistence production systems.

The problems of unfavorable areas need to be addressed, nevertheless, as the welfare of a large number of people depends on improving agricultural productivity and incomes in these environments.

The specific characteristics of unfavorable areas call for research and development approaches fundamentally different from those of the more favorable areas. Environmental heterogeneity, risk, and farmers' responses to cope with these adverse conditions by developing farming systems with multiple activities emphasize the need for a systems approach to agricultural research. Instead of focusing on one or two activities, system-level interventions that exploit interactions among individual activities and complement farmers' coping mechanisms are required. Such an approach would obviously be oriented to managing resources. Often improvements in resource management in marginal areas are more important than improved varieties, and varietal adoption follows improvements in resource base (Morris, Belaid, and Byerlee 1991).

To the extent that food insecurity in unfavorable areas is due to a lack of entitlements, agricultural research directed at improving and stabilizing productivity in these areas is desirable. As unfavorable areas are also prone to environmental degradation, there is growing consensus that resource-centered agricultural research is likely to have greater impact in the long run. The emerging unsustainability of intensive food production in favorable areas also highlights the need for a research approach oriented to resource management. By definition, such research would have to consider several commodities by taking a systems view. The conventional, although highly successful, commodity-oriented research approach is unlikely to efficiently address issues that cut across commodities.

Technology developments through research on resource management can, however, be costly in unfavorable environments that are heterogeneous. The nature of the problem and technological solutions become much more location specific. The scale economy that is characteristic of the broadly adaptable Green Revolution technologies can no longer be realized. A more decentralized research approach in partnership with local organizations and farmers would be required to carry out adaptive research successfully. Such research is likely to require institutional arrangements, methods, and mechanisms of extension different from currently existing ones.

Revitalizing Existing Research Structures

There is little doubt that national agricultural research systems, particularly in Asia, have had major impacts over the past three decades. From a relatively small beginning, they have grown rapidly and now include some of the largest and most developed research systems in the world. Strong collaborative linkages have also been established between the national and international agricultural research centers, especially those of the CGIAR. However, in one sense, the success of these systems has been rather narrowly based on the development of strong plant breeding programs for major food staples, which have continued to contribute to steady growth in productivity in the post-Green Revolution period, as well as to the increased stability and sustainability of food production systems. But these same systems have failed to evolve sufficiently rapidly to provide the knowledge base on crop and resource management needed to exploit the potential of modern varieties and to maintain the quality of the resource base. The established research system has also not been very successful in addressing the problems of the unfavorable environments.

In the 1990s, new challenges are emerging, both on the scientific front, especially the new biotechnologies, and in the area of institutional support and management for research. Institutional structures that evolved during a period of rapidly rising public-sector support for agricultural research are no longer adequate to ensure the efficiency and relevance of research in the 1990 climate of austere budgets. Nor are they appropriate for addressing the complex problems that characterize crop and resource management in post-Green Revolution agriculture. Thus, in moving to the next century, the success of agricultural research will depend on the active exploration of institutional and management innovations to revitalize research systems so that they can deliver the new sources of technical change required for sustainable growth in productivity. In doing this, policymakers will have to consider research systems as being composed not just of a monolithic public sector, but of a variety of institutional structures, including the private sector, and with various sources of funding.

The changing scenario in agricultural research recognizes the important role of beneficiaries and other end-users of research-generated technologies—those who have been referred to as "co-producers" of research outputs (Denning 1994). Recent analysis of research collaborations reveal emerging partners of international, regional, or national agricultural research systems: *direct beneficiaries* of agricultural research and development efforts, such as farmers, farm households and communities, and consumers of agricultural products; *knowledge generators*, such as colleges and universities and centers of excellence; *knowledge utilizers*, such as the research and development institutes that develop research-based technologies as immediate solutions to identified problems; *industry or private-sector organizations* that engage in commercialization of research-generated technologies; and *nongovernment organizations* engaged in development work.

Partnership mechanisms that take into account the participation and involvement of the "significant others" listed above are important for immediate feedback and fine-tuning of technologies. Two groups of players require specific mention here: the farmers and the private sector.

As the focus of agricultural research shifts from commodity improvements to resource management and from favorable to unfavorable areas, partnerships with farmers become more important. Farmers, with their indigenous knowledge, are an important resource that has remained relatively untapped. Farmer participatory research can play a crucial role in developing technologies for crop management in the favorable environments, as well as helping match genotypes to specific environmental niches in the unfavorable environments (Kshirsagar and Pandey 1995). Participation at the grass-roots level may be more efficiently enlisted through farmers' groups, cooperatives, and NGOs. Strengthening research capacity in the social sciences, especially in the NARS, would also be conducive to a more decentralized participatory research approach.

While farmer participation provides a basis for adaptive research, closer linkages with advanced basic science institutions are required to provide the knowledge base for strategic and applied research. Research on resource management would have to draw increasingly from basic research to develop novel technologies. Compared to Green Revolution technologies, which made use of the backlog of scientific knowledge available in the early 1960s, the increasingly more complex problems of degradation of the resource base require a greater flow of basic scientific knowledge from advanced institutes. This is specially true in the case of basic research on biotechnology, which is generally beyond the scope of most IARCs.

Institutional arrangements or partnerships with the private sector that will ensure more equitable access to agricultural technologies are as important as partnerships with farmers and NGOs. For instance, the concept behind the International Service for the Acquisition of Agri-biotech Applications (ISAAA) is to act as an honest broker in the transfer of biotechnologies with application to food systems. Its objective is to develop new institutional mechanisms to effect the sharing and transfer of agricultural applications in biotechnology from the industrialized countries, particularly proprietary applications from the private sector, for the benefit of developing countries.

Conclusions

Notwithstanding the success of the Green Revolution technologies in improving food security, continuing increases in population, emerging trends of unsustainability in favorable areas, and relatively limited adoption of seed-fertilizer technologies in unfavorable areas continue to threaten food security in the future. To the extent that food insecurity is due to a lack of entitlement, the problem of low productivity in unfavorable areas needs to be addressed directly. In the more favorable areas, a dual strategy of protecting current yield gains as well as shifting the yield frontier upward is required.

To arrest the emerging trends of unsustainability, the orientation of research has to shift from the usual one of commodities to resource management. Technologies that make more efficient use of resources and protect the resource base tend to be knowledge intensive. The generation and dissemination of such technologies require approaches that are somewhat different from that used in commodity-oriented research. At the same time, such technologies have to be developed in the austere budgetary climate of recent years.

New problems and strategies require new organization of research. The success of agricultural research in the next century will depend on generating institutional and management innovations to make agricultural research more efficient and relevant. Widening circles of collaboration between agricultural research centers and the private sector, advanced institutes, farmers, and NGOs are required.

The value of the private sector in augmenting the resource base for research and improving the efficiency of using such resource is currently underestimated. With conducive policy and institutional reforms, the private sector has the potential to carry out adaptive research in an efficient manner.

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About the Author

A professor of plant breeding at the University of the Philippines at Los Baños (UPLB), Emil Q. Javier is presently vice chairman of the board of trustees of IRRI and president of the University of the Philippines System. He was founding director of the Institute of Plant Breeding and of the National Institute of Molecular Biology and Biotechnology, both at UPLB. He has also been a member of the Technical Advisory Committee of the CGIAR, a senior research fellow at ISNAR, and director general of the Asian Vegetable Research and Development Center in Taiwan.

The Globalization of Research on Tropical Rain Forests

Kenneth F. S. King

It is now generally recognized that tropical rain forests, because of their unique physiognomy, together with their litter and humic layers, minimize compaction by rainfall of the forest soil, and protect the earth against erosion. Thus, the presence of forests in critical areas reduces the possibility of the siltation of rivers and reservoirs, effectively prevents the denudation of countrysides, and contributes significantly to economic activities in the valleys beneath and adjacent to them.

Environmental Influences of Forests

The contribution of forests to economic activities is of particular importance for tropical agriculture. Indeed, some assert that it is of special significance for human survival in tropical rural areas. In many parts of the tropics, there can be no agriculture, as it is now practiced, without forests. The presence of forests in critical areas, in certain types of watersheds, is an absolute necessity if tropical agriculture is to flourish, if tropical food supplies are to be sustained in brittle, fragile ecological areas, and if hunger and malnutrition are to be contained.

Forests, as is also well known, regulate and purify local water supplies, and are a great reservoir of the world's biological diversity. Moreover, with the rapidly increasing rates of tropical rain forest destruction for crop production, fuelwood gathering, and cattle ranching, it is becoming more and more evident that the release of carbon stored in forests adds to the atmospheric pool of carbon dioxide, and that this destruction hastens the onset of climatic change. This is arguably the most threatening environmental problem of modern times.

Forests and Economic Development

In addition to the biological and protective services that they provide, tropical rain forests are capable of contributing significantly to the development of the often poverty-stricken tropical countries.

Wood is perhaps the most versatile raw material that exists today, and the range of products to which it might be converted is wide: boards, wood-based panels, pulp and paper, protein, lignosulphonic acids and glues, wood sugar, high-quality animal fodder, and a great number of chemicals. Moreover, the technology that may be employed in various forest industries ranges from the very simple to the extremely complex. There is therefore some type of forest industry that can be established in any developing country, no matter what its stage of economic development and level of technological sophistication. In addition, forest industries slip easily into existing industrial and economic structures and, if carefully chosen, do not cause the economic disruption that is sometimes associated with other types of growth industries.

Concomitant with the wide range of forest industries are two other characteristics that make the forestry sector an ideal one to be used as the hub of economic activity in the developmental process. First, forest industries can be highly mechanized or they can employ simple machinery. The advantages of this are obvious. Second, and perhaps more important and significant in the development process, is the fact that forest industries can be both capital and labor intensive.

Forest industries also possess high forward and backward linkage indices. Generally, therefore, the establishment of a particular forest industry leads to the creation of job opportunities not only in the forests, but also in the secondary, tertiary, and other industries that utilize the material that is converted in the primary process.

It is therefore not surprising that the governments of those nations that are endowed with tropical forests seek to use them in order to obtain financial resources to attack the pervasive underdevelopment of their countries. They are, however, generally restrained from doing so because of the perception that the presence of tropical rain forests strongly influences the global environment.

These concerns received emphasis at the Earth Summit held in Rio de Janeiro in 1992. Since then, many restrictions and conditions on the use of tropical rain forests have been imposed by international agencies, the donor community, and nongovernmental organizations on the governments of developing economies. Simply put, the requirement of these institutions and nations is that tropical rain forests should be sustainably managed. In many instances, independent organizations must certify that particular forests are under sustainable management before timber extracted from them can be exported to the markets of developed countries. In addition, economic aid is often withheld from those developing countries that exploit their tropical forests without paying due regard to the principles of sustainable management. What is perhaps of greatest significance is the fact that there are now moves to institutionalize this overarching requirement of sustainability. In other words, if a country cannot prove that it manages its tropical forests in a sustainable manner, its forest products will not be bought by the developed world.

Research Constraints on Tropical Forestry

With the best will in the world, the governments of developing countries are unable strictly to meet this requirement because the knowledge necessary for the sustainable management of tropical forests simply does not exist in most tropical countries.

The basic requirements for the practice of sustainable management are information on the area of forests and their location, the range of forest types, the composition of the forest by species, the rates of growth of different species under various logging intensities, the synecology of the forest ecosystems, the autecology of species, and the stages of succession in various ecosystems. It is only with this kind of knowledge that silvicultural systems might be conceived; that successions might be retarded, hastened, deflected, or otherwise altered; and that size and area limitations might be prescribed to logging with any hope of optimizing and sustaining production, while conserving the tropical rain forests.

In addition, topographic and other physical surveys have to be undertaken in order to determine which fragile ecosystems need to be protected from exploitation, and which areas need to be reserved to protect their biodiversity.

Very few developing countries possess this essential knowledge, and in very few are the financial and trained human resources that are necessary to obtain and analyze the requisite information available.

The *management* of tropical forests in a sustainable manner must therefore be, for many countries, only a snare and a delusion. At best, the attempts at management that are now being undertaken in some developing countries can lead only to crude approximations of what is required. Indeed, the end result of current efforts to manage tropical high forests may well be that neither the financial and economic benefits nor the biological and protective services of the forests are obtained by tropical nations.

A considerable amount of research therefore needs to be carried out if the goals that both the international community and the developing nations have established are to be attained.

Although there has been some useful research on some tropical forest ecosystems, and although much effort has been expended in studying the silviculture of some tropical forests, much of the research and many of the studies have been sporadic, isolated, and ineffectual. As a result, no general theory of tropical forestry management has been developed.

There are several reasons for this failure to understand the rudiments of tropical forestry. Perhaps the most important of these is the fact that the tropical forest is, as described by Longman and Jerrick (1974), by no means a mere collection of, or refuge for, individual organisms, or an accidental mixture of populations. It is a system of a high order of organization, in which the morphological, physiological, and ecological features of individual members are linked together, creating forms and functions unknown outside the forests. Within the limits of inheritance, both plants and animals are modified in the forest community and forest environment, while conversely, the community and, indeed, the habitat itself are altered by the presence of even a single big tree.

Longman and Jerrick (1974) also emphasize that two important factors play a decisive role in the study and comprehension of a tropical forest: its size and the time scale of its development. The problems of size and perspective make all ecological observation and any experimental approach most difficult. In addition, the great life span and age of the organisms involved and, even more, the lengthy development of the forest community, compound the problems.

The close cooperation of many experts of the highest calibre is therefore essential if the problems of research on tropical high forests are to begin to be solved. These researchers must be trained and experienced in tropical forestry for, as Mabberly (1988) has pointed out, early European ideas on tropical vegetation were based on temperate preconceptions. Unfortunately, many of these preconceptions still prevail in tropical forestry thinking and affect the approach of tropical foresters to research about their forests.

A Center for International Forestry Research

It was evident that because of the sheer complexity of tropical forestry ecosystems, a globalized approach to tropical forestry research should be adopted and a central international forestry research agency should be established. The primary objectives of such an agency would be to identify research problems; establish research priorities in various parts of the world; utilize existing tropical forestry research organizations to establish, in all the tropical areas of the world, a network of research stations; obtain resources for globalized tropical forestry research; and monitor the performance of such research. This international center would underpin the field research with investigations on the relevance to tropical forestry of the theoretical concepts that now prevail and which dominate approaches to tropical silviculture and management.

In 1993, the Center for International Forestry Research (CIFOR) was established with these aims in mind. CIFOR is a center, similar in several respects to the International Centre for Research in Agroforestry (ICRAF), but which utilizes existing forestry research institutions in the developing countries. Its primary objectives are to conceptualize, prioritize, coordinate, and monitor research activities.

Iwokrama International Rain Forest Programme, Guyana

At the 1989 meeting of the heads of the Commonwealth governments in Kuala Lumpur, the Government of Guyana offered approximately 400,000 hectares of virgin tropical high forests in the central part of its country to the international community. It proposed that this area should be used for research on sustainable forest management. The offer was accepted.

The specific objectives of the program are to conserve biodiversity, conduct research leading to the sustainable and equitable use of tropical rain forest resources, and integrate environmental and developmental concerns into operational plans that could be applied in similar situations on a national, regional, and global scale (ETFRN 1995). The Iwokrama International Rain Forest Programme is, to some extent, already operational: a law establishing the program has been enacted, an international board of directors has been appointed and has already held its first meeting, a program of work has been formulated and approved, and a director general is in place.

It is suggested that formal arrangements be made to combine the structures of CIFOR and the Iwokrama Programme. Such a rationalization would concentrate research efforts, utilize scarce human and financial resources more effectively, and enhance the contribution of the international community to the development of tropical countries.

There is no alternative to a global approach to tropical forestry research if the problems of tropical forestry development are to be solved.

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known as "community forestry" was conceived and developed while Kenneth King was assistant director general at FAO. A 1968 monograph by him on agri-silviculture was the inspiration for the modern concept of agroforestry.

The Globalization of Agricultural Research: The Example of Southern Africa

M. L. Kyomo

It is a well-known fact that problems in agricultural and natural resource management are location specific. Nevertheless, the international agricultural research centers (IARCs), through the coordination mechanism of the Consultative Group for International Agricultural Research (CGIAR), have been able to generate and package technologies that resulted in the Green Revolution for Southeast Asia and Latin America during the 1970s. This happened because of the existence in those regions of strong national agricultural research systems (NARS), including strong supportive services such as agricultural education and agricultural extension systems. This model of increasing agricultural productivity to solve hunger and malnutrition in developing countries has been promoted in other developing regions of the world with varying degrees of success.

Introduction

Why is globalization of agricultural research being sought at present and why was it not encouraged in the past? The dwindling allocation of resources to research and human resource development at the international and national levels, including weak support to agricultural extension in NARS, has made it necessary for both types of institutions to use their scarce resources to maximum advantage. There is also a need for the two entities to develop a solid working relationship so that they may bring about a Green Revolution in regions where it did not happen in the past.

In this paper I use the example of Southern Africa, where a regional agricultural and natural resource research and training secretariat was able to bring several IARCs to work with a group of NARS, including faculties of agriculture, forestry, and veterinary medicine and later including the regional coordinating units in natural resource sectors such as wildlife, food security (including agricultural extension), forestry, fisheries, land, water, and the environment.

Regional Agricultural and Natural Resource Research and Training Networks

Problems of an ecoregional nature where identified in the region with the assistance of donors. The DEVRES study commissioned for SADC in 1985 and funded by USAID concluded that agricultural research could help member states solve their food-security problems if it were oriented to meeting the problems of small-holder farmers. It was DEVRES that also felt that a regional coordinating secretariat of the NARS in the region could bring strong and weak NARS together to work for their mutual benefit in conducting and formulating priorities for research, extension, and training. As a result, the member states of SADC agreed to establish the Southern African Centre for Cooperation in Agricultural and Natural Resources Research and Training (SACCAR) in 1985.

Second, through the DEVRES study and regional initiatives, the following important research networks were identified as being able to solve the problems of small-holder farmers:

- Sorghum and Millet Improvement Research and Training (SMIP), executed by ICRISAT;
- Grain Legumes Improvement Research and Training (GLIP), executed by CIAT (beans), IITA (cowpeas), and ICRISAT (groundnuts);
- Agro-forestry Research Network for the Savannah Grassland-Woodland Ecologies, Executed by ICRAF;
- a Network for the Conservation and Utilization of Plant Genetic Resources, executed by the NORDIC Gene Bank;
- vegetable research, executed by AVRDC;
- maize and wheat research improvement, executed by CIMMYT;
- training in agricultural research management, executed by ISNAR;
- aquaculture research and development, executed by ICLARM;
- a research program on land and water management, executed by NRI and a consultancy firm in Frankfurt, Germany;
- establishment of centers of specialization for graduate courses in food, agriculture, and natural resources in universities across the region, managed by various universities in SADC and SACCAR;
- agricultural information sharing, executed by SACCAR;
- impact assessment and policy analysis of regional and national research projects and programs and their monitoring and evaluation, executed by SACCAR.

Execution of the Regional Research Networks

TAC commissioned a study during the late 1980s on how IARCS could work closely with the NARS through a regional coordinating body such as SACCAR. The board of SACCAR stated that IARCS would be given the execution role if they worked with the NARS in the following ways:

- identified research priorities together;
- monitored and evaluated research together;
- published research and training findings together;
- pooled and shared the resources allocated by the CGIAR and donors to IARCs and the region for conducting research and training programs.

It was felt by the NARS in SADC that if the above guidelines were followed, the concept of IARCs as donors and as "elitist organizations," which isolated them and their findings, would disappear. In the SADC region, NARS and SACCAR appreciate that although the IARCs have a global mandate of conducting strategic research whose outcome has wide application, they can also execute a regional network that is based on their mandated commodities (Kyomo and Martella 1995).

Other Management Issues of the Regional Research and Training Network

The networking mode evolving in the SADC region envisages that a commodity or program leader in a NARS or training institution undertakes the leadership of coordination (i.e., administration, germplasm distribution, training, etc.) of the network. Funding for the network comes from both the host national institution and other member states and donors through the regional body, i.e., SACCAR. The participating network members are the commodity leaders from member states and they have the responsibility along with the network coordinator for training staff, developing the technology, and ensuring that the technology gets transferred to the stakeholders. There must be at least two participating member states for a network to be viable.

It is obvious from this description of the new collaborative networking mode evolving in Southern Africa that the networks are led by national and regional research or training Institutions and that the IARCs have only supportive and catalytic roles.

Mechanisms of Execution of the Regional Research Networks

The members of the statutory board of SACCAR are the national directors of agricultural and natural resource research in the NARS and representatives of the deans of the faculties of agriculture, forestry, and veterinary medicine. This board provides broad guidelines and priorities and approves plans of action.

There is also a committee of the deans of faculties of agriculture, forestry, and veterinary medicine from all universities in the region. This committee assists SACCAR's board in setting priority needs and in guiding and monitoring training activities.

The project steering committees guide and monitor research projects.

The executing agencies, the majority of which are IARCs, are responsible for the actual implementation of projects. They are answerable to the board through SACCAR as well as to the NARS. They also report to their respective boards and to donors funding the specific network that they are executing.

The NARS managers play a dual role. As members of SACCAR's board, they assist in providing the broader guidelines and priorities for the region. In addition, they are directly responsible for the day-to-day management of the regionally executed projects located in their own countries.

Regional research planning workshops are organized annually by the networks. These serve as a vehicle for identifying priority research themes for regional cooperation.

The underlying assumption is that the NARS are strong and capable enough to take a leadership role in many of the regional activities implemented by SACCAR and that they also have the resources and time to handle the day-to-day management of the regionally executed projects.

Lessons Learned

Since its inception, SACCAR has made good progress in identifying regional projects, soliciting donor funding, and coordinating the implementation of projects in collaboration with donors, IARCs, and NARS (USAID/RCSA [Botswana], Ministry of Agriculture of Botswana Government and NORAD 1996). The secretariat is presently coordinating several projects and subprojects that are being implemented by various executing agencies. In most cases, the executing agencies are IARCs. As discussed in the earlier section, a number of mechanisms have been put in place to facilitate this process. SACCAR also has the support of member states in fulfilling its objectives. This clearly demonstrates the need for regional cooperation.

However, during this process, SACCAR has learned several lessons that are worth sharing with other regions. These could help facilitate the formation of efficient regional cooperation in research and training initiatives.

- It is important to have strong, well-established NARS with a willingness and commitment to accept a greater management responsibility for the implementation of regional collaborative research. There must also be a commitment to regional collaboration by member state governments. This is vital for successful implementation of regional projects/programs.
- Each member country should have well-defined, well-articulated policies, strategies, and priorities for research on and management of national agricultural and natural resources. Regional collaborative initiatives should be based on these identified priorities.
- There are a number of stakeholders involved in the implementation of regional activities. For successful implementation of regional projects/

programs, the roles and responsibilities of each of the stakeholders should be well defined and clearly understood before any project is begun.

- In terms of developing regional research or training projects, collaboration through networks is much more desirable than collaboration through a project where most of the activities, capital, and infrastructure are concentrated in one county. If the project is divided into several components and then these individual components are located in countries where they are considered to be of high priority, then the chances of sustaining these initiatives are greater. Unless a member state identifies itself with the problem being addressed and unless this problem is considered a priority in that country, it is highly unlikely that the research or training effort will survive in the long term.
- Long-term commitment of funds and sustainability issues should be given high priority in the design and implementation of regional projects/programs. The lack of a firm commitment by donors for continuous support for regional projects/programs is bound to be one of the major constraints in achieving overall project goals. A clear strategy for transferring the responsibilities for financing, administration, and coordination to the NARS should be spelled out in the project documents and agreed upon by the member states.
- In the past, inadequate attention was given to the need for assessing the impact of regional research and training projects. Ex ante assessment of the benefits and costs of regional projects should be given a high priority during project formulation. Monitoring and evaluation should form an integral part of project implementation, and the information generated should become part of the management tools for determining the future direction of project activities. Developing a need-based monitoring and evaluation system should be the responsibility of the executing agency.
- In the majority of on-going regional research activities, considerable attention has been given to expanding the frontiers of technology. This approach assumes that once the technologies are developed, it is the responsibility of the member NARS to field-test and disseminate the technologies and recommendations. The executing agencies assume that the transfer of technologies is the responsibility of the NARS. To a certain extent, this affects the level of impact of the regional projects and programs. Therefore, in developing a project/program, adequate attention should be given to technology transfer.
- It is not possible for a regional organization that is charged with the responsibility of coordinating a large number of regional activities, such as SACCAR, to provide adequate technical guidance for implementing regional projects/programs. The technical guidance should come from member states or regional scientists. Successful implementation of regional projects requires a strong steering committee with experienced scientists as members in order to provide technical guidance to the executing agency.

Broadening the Definition of NARS

It has correctly been argued that the NARS should include public agricultural research institutions, universities, farmers' organizations, and NGOs. In SADC, public research and training institutions have worked closely together. A few private research foundations such as those specializing in food and cash crops have been affiliated with SACCAR. The cooperation between SACCAR and farmers' organizations and NGOs has not been formalized but these agencies have participated in various SACCAR workshops. There is a possibility under SACCAR in SADC, to gradually develop mechanisms for broadening the range of institutions that make up a NARS.

Concluding Remarks

The challenge of development and transfer of technologies in agriculture and natural resources rests on the fact that the most efficient and least-cost means for development and transfer of technologies is through collaborative national regional and international research networks. The IARCs have been involved in the development of crops and livestock networks and, similarly, natural resource management will be addressed under ecoregional initiatives using the networking mode.

The vision for globalization of agricultural research, therefore, should build on the lessons learned from collaborative research, training, and information exchange in the areas of agriculture and natural resource management, especially from regional and international networks. The participation of NARS in priority setting at TAC and their representation in the CGIAR have elevated their participation from a regional to a global level. The Special Program for African Agricultural Research (SPAAR), which can be regarded as a small CGIAR, has been responsible for encouraging the regions in sub-Saharan Africa to embrace the networking mode. In Southern Africa, the framework for action that was developed jointly between SPAAR and SACCAR was aimed at involving the donor community in funding the research, training, and information-sharing networks that had been developed from the grass-root level of NARS.

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Rural Misery and Agricultural Decline in Resource-Poor, Fast-Growing Countries

Klaus J. Lampe

It is not known when and at what final figure human population will level off. What we do know is that the world community has to be prepared for a population of more than 10 billion around the middle of the next century.

Introduction

Technically, it is possible to develop the knowledge, systems, and tools to produce enough food in most resource-poor, fast-growing countries (RFGCs) on a sustainable basis. However, the present neglect of rural areas, of agriculture, and specifically, of agricultural research makes it unlikely that we can generate the knowledge needed within the time left to us.

Food aid is not an effective policy to achieve sustainable food security for RFGCs. It should be limited to catastrophic situations, for it destabilizes domestic production and cannot serve the long-term needs of food production in RFGCs. Food aid in future will be confronted with additional challenges since one of its driving forces, the subsidy-stimulated overproduction of food in industrialized countries, will be eliminated with the full implementation of the General Agreement on Tariffs and Trade (GATT).

The lack of food is, first and foremost, an expression of the inability of a society to make this basic need a priority in national policy formulation and to enforce such policies if they do exist. The most important factors for the promotion of agricultural production are

- political willpower to implement policies conducive to food production;
- promotion of rural development in general;
- the redirection and proper pooling of human and financial resources toward food production in the broadest sense—from research to marketing.

The Present Scenario of Fast-Growing Countries

Half a century ago

- World War II was over.
- The United Nations was established.
- A new global monetary system was created at Bretton Woods.
- The globe had 3.3 billion people less to feed than there are today.

Reviewing the changes that have taken place over the last 50 years, the global community of decision makers, in both the public and the private sectors, have no reason to be satisfied. Our dream to fly to the moon came true—just less than 10 years after the political decision to finance the project had been made and a coordinated multidisciplinary effort launched. Our dreams to eliminate hunger, malnutrition, unemployment, poverty, however, remain just dreams after 30 years of what is called *aid*—in sharp contrast to today's reality.

- 2.9 billion more people than 1945 live in low income countries.
- 569 million people—following official statistics only—are hungry, undernourished or malnourished.
- 14 million children under the age of five are dying every year because of hunger or hunger-related disease. This is equal to the population of New York and London combined.

Today, our most frustrating dilemma is our inability to provide access to food for everybody on this globe or to have, at the very least, a vision to make that happen within an acceptable time frame.

There will be no long-term future if the world community is not willing and prepared to act now. We cannot claim that we need more information and more time to plan. What we need are decisions made by responsible leaders in the public and private domains. We cannot any longer claim that we do not have enough financial resources to make these decisions. What we need is the willpower to allocate resources, not on the basis of short-term benefits but on the basis of long-term needs; this are uneasy decisions that will become more difficult over time.

The resource-poor, fast-growing countries of Planet Earth could serve as a global test case of our common preparedness to act beyond emergency cases of the first order, such as the Balkans, Somalia, Rwanda, and Ethiopia. The situation in these countries has been a painful lesson for us. Too often, food and disaster aid had been preceded by military aid of excessive proportions. Only by mobilizing our ability to plan and act jointly in a more responsible manner toward global needs might we be able to prepare our world for a better future.

Nations with a high population growth rate cannot be lumped together in one category. Further differentiation is essential. Saudi Arabia and Nepal are both fast-growing countries in terms of population growth, but beyond that fact, the two have little in common. Taking into account the geographical, economic, and political conditions of the fast-growing countries (FGCs), their size and, specifically, their available natural resources, their opportunities to absorb and finally overcome undue growth are exceedingly diverse. One must also take into account, the levels of national unity, of nationhood, of political maturity, of education. These elements are crucial for slowing down population growth and accelerating economic and social development. The carrying capacity of a given environment, including its further development through capital transfer and new technology, the possibility of importing food or labor, are key components in the equation to realize the "limits of growth."

When these differences are included in the equation, the most endangered nations are obviously the resource-poor, fast-growing countries with limited opportunities to generate employment.

Most of the countries with the highest population growth rates over the last 10 years are experiencing the highest rate of urbanization as well. The eight major Latin American countries (Venezuela, Mexico, Argentina, Brazil, Chile, Columbia, Puerto Rico, and Cuba), with a total population of 276 million, face urbanization rates between 70 and 90 percent.

In 1990, the world had 35 cities with more than 5 million people, 23 of them in less-developed regions containing 2l8 million people. By 2010, the number of such cities is expected to increase to 47 with a population of 508 million. Around the same time, even in Asia, more than half of the population will be urban dwellers.

The real numbers of the world's unemployed and, equally important, underemployed is not known. We know that rural unemployment and the lack of adequate income has led to uncontrolled migration. The generation of new job opportunities is not flagging only in the RFGCs. In industrial countries, the average unemployment rate was 6.5 percent in 1992, more than 10 percent in Canada, France, Australia, Germany, Italy, Spain, and Hungary. The total number was about 35 million, with 29 million in OECD countries alone. This does not include the number of partially unemployed people; however, it is known that these figures are on the rise as well. This factor will not only affect the opportunities for new employment in RFGCs, it will also alter the types of jobs possible in the future.

Access to food, even in most of the fast-growing countries, has up to now been a question of financial resources only. However, what is very often ignored is that the resource base for agricultural production will not allow the sustainable production of enough food for all at acceptable prices with the present technology. In most of the fast-growing countries, agriculture is already practiced on marginal lands, land that encroaches on forests and fragile ecosystems, thus ensuring long-term negative effects. The vicious circle of growing poverty and population growth is only too well known.

Where land tenure and land-use systems hinder the ecological and social decision-making process, making it difficult if not impossible to set priorities conducive to sustainable food production, all efforts to make food based on sustainable systems available are bound to fail.

A perspective for a rural life that would be attractive to the current young generation is absent in most Third World countries, specifically in those with fast-growing populations. Neither the private nor the public sector has, beyond a very few promising examples, developed large-scale, multisectoral programs that would allow the younger generation to choose among several skills and professions without leaving their rural homes. The exodus of our rural populations has been created by ourselves, and in too many cases, for those who move, it is merely a case of trading rural poverty for urban poverty.

Too many political and economic leaders have either lost their links to their rural roots or—even worse—are ignoring them. The role models in schools, newspapers, radio, and television are all urban, based on resources available to only the tiny middle and upper classes, and in most cases, not sustainable. Electricity, drinking water, roads, information systems, alternative jobs outside agriculture: we have wanted to bring them to the villages for the last 50 years. The balance sheets of these programs are less than encouraging, and the migration of rural people is a consequence of—and the only logical reaction to—the situations that exist today in these societies.

Education is the key to all development. We do not need expensive studies to explain the roots of population movements in resource-poor, fast-growing countries. What we need is to reflect on our failures, find out why they occurred, produce solutions, and implement them as soon as possible. The decline of rural education in both quality and availability is one of the causes and effects of increased migration. Why should industry invest in an environment where skilled, educated labor is not available?

Health services are often more than adequate, even in fast-growing, poor countries, but only in urban areas and only for those who can afford them. In rural regions, only the basics are provided—or they do not exist at all. It is ironic that while an understanding about hygiene as a lifesaver during the birth of a baby has reached the huts of the poor, and has reduced the infant mortality rate, we seem to be unable to provide the resultant population with a secure base for living in dignity.

Two underemployed children cannot support two old parents, but 10 can. That is a solid fact that is understood and acted upon in the Third World. In the modern, wealthy, industry-dominated part of our globe, the support of an extended family has been replaced by a public security system that often provides the economic base for survival. But small families are not the only result of this system. It has also contributed to the erosion of the family as a security system beyond the financial component. The "old folks home" as a social answer to what to do about the older generation is something that can be questioned. The preschool child-care facility as an adequate ersatz mother in a so-called working family can be questioned as well. Luckily, the developing world, where more than 50% of the population is below the age of 30, has not turned in that direction. Yet, we still have time for new solutions that show more care for the elderly, for the new generation, and for a better common future.

As long as there has not been a financial system developed for RFGCs upon which individuals can rely in old age, and in which they have long-term confidence, family planning for the poor must include sharing the burden of family risks and old-age support among as many individuals as an extended family can support. That is why their definition of family planning differs from that of the conference room.

A public social-security system cannot be maintained without political stability and confidence in leadership, continuity, and economic growth. Given these facts, it becomes very clear that the present scenario of RFGCs and their difficulties in producing enough food can only be solved through combined efforts related to employment generation, education, and advancement of rural society.

The Preferred Scenario of Food Production in Fast-Growing Nations

One of the unquestioned lessons learned over the last 50 years is that food production and access to food cannot be dealt with in isolation from a program that includes all the modern sectors of economic development. Regional and global trade arrangements (EU, NAFTA and GATT) are forcing fast-growing countries to integrate their economic planning in the new and emerging regional and global systems. Since these countries are being forced to use their limited foreign currency resources for labor income, other uses of this income, such as expenditures for food consumption and generating investments, have to be minimized.

From experience, we know that the South would be ill-advised to copy the production and consumption patterns of the North. Today, the G7 countries consume about 224 gigajoules of commercial energy per capita per year, 19 times higher than Africa, nine times higher than Asia. The resources of our globe will not allow the South to follow the North's example; employment and economic growth must be achieved in the future with much fewer nonrenewable inputs, specifically energy. High investments in research are needed to achieve that. Low-energy, low-capital-input workplaces, serving predominantly local and regional markets, must be developed in very large numbers to avoid an ecological and social collapse that will affect the entire world.

Everything experienced so far clearly shows that a more attractive agricultural production pattern for food and non-food products can lead to more attractive workplaces that are more acceptable to the younger generation. They can at the same time be environment-friendly and energy-conscious. Such an approach must, however, be part of a comprehensive effort in the development of rural areas—one given a clear priority over urbanization. Demand-driven agricultural production will have a chance to stimulate investment in agriculture. The failures of the past have often been rooted in the promotion of production schemes without proper market prospects.

To repeat only the rural development efforts of the 1960s is not a solution. However, instead allowing the 10 million cities to grow further, 100 urban centers in rural areas with about 100,000 inhabitants could and should become an alternative. Agriculture must provide not only food but the raw material for agro-based industry. Fiber and oil plants, agroforestry products, and products for the processing industry are only examples for possible inter-linkages between "rural urbanization" and agricultural production.

The preferred scenario includes a departure from the present isolated, delinked efforts of the public, the private, the government, and the nongovernment sectors. A successful turnaround must also include an end to the present uncoordinated support from bilateral and multilateral organizations that compete in an unhealthy manner for promising pilot projects. The Schumacher slogan "small is beautiful" has its merits only if these individual efforts fit into a harmonized, nationwide program.

Real progress can be expected if sincere and professionally sound efforts at the local, regional, and national levels are carried out in cooperation with national and international organizations, as well as with the private sector. Such efforts, specifically at the local level, call for close cooperation and collaboration with the respective target groups, whose knowledge, interests, expectations, and experiences are the most important assets in the battle for long-term success. If massive efforts are made towards achieving decentralization, transparency in decision-making, and motivated leadership, the confidence of the rural population might be regained—an essential precondition for investment and growth.

The past scenario of most fast-growing countries was determined by competition between socialistic and capitalistic systems. Many countries have, in the short run, benefited from technical and financial assistance linked to vote trading at a government level. The present scenario of rural misery and agricultural decline is rooted more in the results of cold war policies than in the inefficiency of farming communities. No nation should expect loyalty from the part of its society that is most neglected, exploited, and ignored. In most resource-poor, fast-growing countries, agriculture and food production belong to this part of the society and are traditionally seen as backward—contrary to "modern life."

Food prices are kept low, often with the help of imported, highly subsidized, staple foods from industrialized countries. This keeps the urban poor under control, and the rural areas at best on subsistence level. This policy needs a very drastic change. The economic depression, the shrinking resources for financial and technical cooperation, will provide the pressure needed to plan for and implement decisions that have not been thought realizable before. A fundamental change at the country level for many fast-growing states is mandatory for their survival as nations. The process is painful, not without risks, and costly in many ways. However, it must be noted that there is no alternative to a policy that gives priority to rural areas, to the development of villages and rural towns. To continue "business as usual" must be seen as suicidal.

In just 13 countries of Asia, in the next 15 years, about 400 million people are expected to leave their villages. The growth of slums in mega-cities, urban unrest, and the destabilization of society seems to be inevitable. And there is no doubt that this trend can only be slowed down if all the forces needed to make the necessary changes can be mobilized.

A "countryside-first" policy must stimulate the brightest young people of all sectors to work for a longer period in rural areas. It must be emphasized again that "countryside" and "rural areas" are, in this context, not identical with village life and small-farm agriculture. The policy advocated includes developing townships to provide not only all the services expected today but also the range of job opportunities the young generation feels attracted to. A concept based on specific national needs has to include all basic sectors crucial to providing a long-term perspective, an attractive alternative to the present urban scenario.

One of the most crucial cost factors is that for infrastructural development—too often neglected in many fast-growing rural areas. But alternatives to the present system of, for example, financing and building roads, are possible. In many instances, the national armies are well equipped and would be capable of acting as a national labor force and building, for example, secondary roads. Similar services could be provided for the establishment of a telecommunication system, health clinics, reforestation, and erosion control. Cost-cutting, innovative, management systems have helped thousands of private companies in the last 10 years to overcome previously unforeseen economic challenges. The public sectors, national and international, have to seek innovative approaches for a better division of labor and responsibility sharing.

Only a small minority would now claim that the organizations that exist to help decrease the North-South gap have been successful. They have not, and we all have to share in the blame. Administrations grew, national interests hampered decisions, and an influx of new organizations created new administrative jobs but seldom increased the efficiency and effectiveness of services where they were needed most: in the countryside.

International donors and the national governments financing these organizations have no other choice but to review, reframe, restructure, and reorganize all international and national organizations with a view to achieving a higher degree of flexibility, effectiveness, and efficiency. The model for this would ideally be that of successful private-sector organizations. Such a fundamental change makes cooperation with the private sector and the NGOs mandatory.

Incentives for increased, sustained food production cannot, however, be limited to a few political and administrative decisions, to a budget increase for extension services or for market information. The main reason for the failure of so many isolated efforts of bilateral and multilateral institutions has been their piecemeal nature, the lack of national policies, and the lack of integration with all the sectors that influence development in "rural areas." Joint activities with UNDP, the World Bank, ILO, WHO, UNIDO, to name only a few, and all the respective private sectors and bilateral agencies in one country, have never taken place. But there is no doubt that such coordinated efforts, with their respective structure for fast and competent decision making could lead to a long list of success stories. The know-how for such actions is there; the structure to make it happen is not yet in place. How to produce enough food of acceptable quality in a resource-responsible manner, at affordable prices, attractive enough for farmers to serve local, regional, and national markets, still remains the key question to be answered.

Under the assumption that a reasonable supply of agricultural inputs, credit, and market facilities are established, the problems we are faced with can be "reduced" to "highly productive sustainable production systems." The world community has to produce, within the next 40 years, about double the food we harvest today. If we want to eliminate hunger worldwide, the estimates for the middle of the next century are going well beyond two times the present production. This has to be done with less water, fewer labor and energy inputs, lower costs, and first and foremost, much less land than today.

According to FAO data, every year more than 7 million hectares of arable land are lost forever because of erosion, land degradation, urbanization, industrialization, and infrastructure development. If this rate continues and no "new" land is put under the plow, one day we will lose the world's farmland of today. The chances for new land development, especially in Asia, the fastest growing continent in terms of population, are extremely limited, if not nonexistent.

For almost all fast-growing, larger countries, an increase in food production must come from yield increases and not from area expansion. The introduction of new high-yielding plant varieties, and those tolerant of biotic and abiotic stresses, has helped avoid widespread hunger in areas of the world that grow rice, wheat, and maize. Cassava, potatoes, sorghum, and millet programs have, together with integrated pest management (IPM), brought hope to numerous small farmers, even those in marginal areas. However, today, in too many cases, the difference between the highest yields of the best farmers and the most successful research stations in a given ecoregion are marginal. And too often they are achieved with systems and methods not sustainable in the long run.

The underlying principles of what is called "sustainability" are much older than written history. And, in the past, whenever these principles were neglected, agricultural land was transformed into wasteland, and the human societies depending on that land moved or even vanished. History will repeat itself if we do not find solutions for achieving an equilibrium between food needs and environmental protection. There are reasons to believe that technologies for long-term food security can be developed.

Through aggressive research efforts, most staple food crops can be altered with the expectation of increasing yields by about 50% through higher nutrient uptake efficiency, and better use of solar radiation, water, and other inputs. Indirect increases are possible through enhanced resistance and tolerance. Linked with new IPM technologies, IRRI is, for example, expecting to raise the yield barrier for rice in the tropics from today's 10 tons/ha to about 15 tons/ha.

Nitrogen fixation linked to the rice plant was once a dream; today it's part of IRRI's research program. What might be possible for rice should not be impossible for other grain crops such as wheat, maize, and barley or sorghum. Genetic enhancement can also be used as a tool for preventive medicine. Worldwide, at least 190 million pre-school children are at risk for vitamin A deficiency. Each year, some 700,000 new cases of severe vitamin A deficiency occur, and 350,000 victims go blind. Iron-deficiency anemia affects at least 800 million people worldwide. About 50 percent of pregnant women and 20 percent of pre-school children suffer from this nutritional disorder. Modern tools of breeding (marker technology, genetic engineering) can help increase the amounts of specific nutrients in staple food plants with tremendous economic and social effects, and without significant additional inputs.

Hybrid seed in its present form allows farmers to increase yields by about 20 percent. The cost of this is the loss of original genetic material and market dependency for seed that has to be purchased for every new crop. There is reason to believe that hybrid vigor can be mobilized genetically in a given food crop so that farmers will be able to produce their own seed.

Most staple food crops are annual plants that have to be sown after every harvest. This process, including land preparation, is both costly and labor intensive. On fragile land, it often leads to erosion. Studies are underway to develop a perennial rice plant, for example, that can serve in erosion control as well—specifically for small farmers. There are many more examples, like the true potato seed or plants that produce their own insecticides or even herbicides. The knowledge base for this research exists. The infrastructure to undertake this research exists as well. To finance the research necessary to produce enough food, based on environmentally friendly principles, would require less than the investment needed for the most modern airport recently inaugurated.

However, without improved agronomic practices, the advantages of higher genetic potential cannot be exploited. Improved soil-water-nutrient management and crop-rotation systems are needed to optimize yields on a long-term basis. These technologies are region-specific, especially in rainfed production systems, so research results must be adapted or even specially developed to meet local needs. To make that happen, national systems need not only financial support—as provided through a new World Bank initiative, for example—but first and foremost, a reshaping to provide more flexible and performance-oriented management structures. Experience with other national and international research centers has already proven that useful results can be achieved in a shorter period of time at low cost through close, partnership-based linkages.

Public extension services and agricultural training centers often lack trained and motivated staff, as well as funds and modern knowledge resources. Their output in the past has too often been affected by these and other shortcomings. National governments will, in most cases, be unable to introduce significant changes themselves without additional support. It seems worthwhile therefore, to explore possibilities to link applied/adaptive research stations directly with farmer participatory research and extension services. These would be managed primarily by the farming community itself in cooperation with the public sector, the private sector, and NGOs, following accepted common principles and division of labor. Such low-cost systems can expect a higher acceptance rate. and a higher speed of transformation, with less risk of failure.

Building Blocks for a New Strategy

Promoting food production in RFGCs, given new policies, new structures, and new systems, must concentrate on the following areas:

- Knowledge, systems, tools, and technologies developed for similar societies and ecosystems need to be identified and adapted to respective needs.
- Research needs to be prioritized to enhance environmentally friendly food production.
- Systems for rapid and appropriate information/knowledge exchange need to be developed, as well as ways of transferring technologies to end users at low cost.
- Land and water will become severely limiting factors; agriculture will have to withstand competition from direct human and industrial needs. Since RFGCs are specifically affected by erosion and loss of water resources, low-cost measures to avoid such losses are imperative. To produce 1 kg of rice needs 4,700 liters of water, for example. It is possible for good agronomic practices to reduce water consumption. At IRRI, for example, projects are underway to reduce water needs for irrigated rice by up to 50 percent. Through new methods of soil preparation and seeding, labor costs can also be reduced considerably. Erosion control is feasible and must become attractive for farmers through such things as perennial food or cash crops.
- Resource-poor countries are also poor in energy. The primary energy used is firewood. Food preparation depends on wood, and women, mostly, have to walk for hours to collect it. Cooking technologies that are acceptable and or adaptable to different needs exist today; they need to be documented and disseminated. International research must be promoted to find ways to reduce cooking time for the most important staple foods. Again, plant breeders and food technologists must collaborate to achieve success here. Low-cost, safe and easy-to-handle pressure cookers and crop varieties with shorter cooking times are some of the possible solutions.
- Fast-growing, multipurpose trees have been studied for more than 50 years. Documentation exists. What is needed is to adapt the technological knowledge to the socioeconomic and ecological conditions of a country or district.
- The breeding of new varieties has proven to be the most effective and efficient avenue of introducing progress. Breeding staple food crops for RFGCs must include the following:
  - higher and more stable yields;
  - improved storage cooking and eating quality;
  - tolerance against abiotic stresses such as drought, floods, cold, and adverse soil conditions;
  - resistance against pests and diseases;
  - low water consumption;
  - high content of essential micronutrients and vitamines;
  - high efficiency in nutrient uptake;
  - low energy needs for processing (cooking);
  - hybrids—specifically apomictic plants that can be multiplied on-farm—to help, first and foremost, resource-poor farmers producing

under marginal conditions.

- Without animals, most farming systems are not sustainable. RFGCs often lack the capital even for small-scale mechanization. Draft animals are needed and their improvement is crucial for enhanced production. Animals can often make use of agricultural by-products and provide additional income to people and nutrients to soil. Research and development have been done in the following areas: triple-purpose cattle (draught-meat-milk) and small ruminants, such as sheep and goats, and poultry.

The last five decades cannot be seen only as half a century of failures. Hundreds of success stories remain untold. They are mostly buried in gray literature, internal reports, and unpublished studies. In many cases, isolated ideas failed to be successful because "external" factors influenced the program. Donor impatience, sudden changes in priorities and policies have stopped many promising efforts prematurely.

What seems to be needed is an interinstitutional review, assessment, and exchange of information about successes and failures over the last four decades of development programs for rural areas.

In each of the three continents in question, a very small number of projects, all large enough to serve as representative samples, should be selected as testing grounds for jointly planned, prepared, and implemented activities all based on the same goal:

> The improved well-being of the total population of a given rural region through the development of sustainable production systems for food and non-food products contributing to the generation of acceptable income levels through a wide spectrum of employment opportunities.

Such joint efforts could become a reality if, for example, a council representing the host country and all multilateral and bilateral organizations would form a development consortium in which representatives of the respective regions have a strong voice.

Conclusions

- It is an illusion to believe that massive fund raising for rural initiatives will be successful on short notice. It is an illusion as well to believe that we can ignore the present trend toward urban poverty, social unrest, and civil war due to unacceptable levels of poverty. In the countrysides of the Third World, we are running out of time to develop sustainable and acceptable living conditions.
- The sharing of existing know-how, available budgets, and experiences within the public and private sectors, including NGOs, might provide the base for a new beginning. This could lead to increased public awareness and a new level of confidence that might, in turn, lead to new partnerships.
- The billions of jobs needed in the next century, predominantly in rural areas, form a challenge we all have to face. Sustainable food production

must become part of a larger setting of sustainable life systems, where environmentally sound, socially attractive, and the generation of acceptable long-term employment is seen as the centerpiece.

- Nobody can expect food production to be doubled within the next 30–40 years as long as those who are supposed to produce this food, the farmers, are neglected, exploited, their profession disregarded, and their living environment accorded lowest priority.
- To mobilize leaders in the public and private sectors, to give confidence to public and private investors, an international code for a "rural future program" is urgently needed.
- The code to be formulated must include the basic principles, policies, and guidelines for long-term mobilization of human resources in, and for, the countryside. It must ensure professionalism, reliability, integrity. It must serve as a guarantee to overcome the key obstacle for change: widespread ignorance in action.
- It would be an illusion to believe that we can protect the environment without feeding the people, and feeding people, without protecting the environment, is courting disaster.

About the Author

Klaus Lampe earned his PhD in agriculture from the University of Bonn. Since that time he has served as a government advisor to the Ministry of Planning in Afghanistan, head of the Afghan-German Agriculture Regional Research and Development Program, head of the Agriculture Section of the German Technical Assistance Agency and Ministry of Economic Cooperation, and head of the Department of Agriculture, Forestry, Fisheries and Health for the German Agency for Technical Cooperation. Most recently, he was director general of the International Rice Research Institute in the Philippines, retiring from that position in 1995.

Towards a Global Partnership for Research on Water Management: Current Status and Future Prospects

Roberto L. Lenton

Over the last few years, a strong consensus has emerged on the need to forge a global partnership bringing together all those engaged in programs and projects for sustainable water management. This concept was given concrete expression in 1996 with the establishment of the Global Water Partnership (GWP) under the cosponsorship of the Swedish International Development Agency, the United Nations Development Programme, and the World Bank.

Introduction

Although the GWP's overall objective is to promote integrated water management programs that follow the principles agreed upon at the 1992 Earth Summit, it has also in its early stages devoted attention to specific areas of water use where the needs and opportunities for concerted global action are great. One such area is the management of water resources for food security in developing countries—a topic of unquestionable importance in view of the vital role that water plays in producing food and generating livelihoods for the world's poor. Another is the challenges presented by the growing scarcity and deteriorating quality of fresh water supplies for agriculture.

This call for increased global cooperation on water management action and research has developed in parallel with a broader consensus on the need for a global alliance for research on agriculture and natural resource manage-

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ment—aimed at alleviating poverty, increasing productivity, and arresting environmental degradation. This consensus was recently given impetus by the Global Forum on Agricultural Research, which brought together a variety of actors engaged in agricultural research to explore needs and opportunities, the scope for collaboration, and practical measures to strengthen partnerships. This Forum adopted a wide-ranging "Declaration and Plan of Action for Global Partnership in Agricultural Research," which called for mobilizing the world scientific community in support of a global partnership for agricultural research (CGIAR 1996).

This chapter therefore brings together these two interrelated efforts to forge global partnerships—one for sustainable water management, the other for research on the management of agriculture and natural resources—by addressing the need for a global partnership for research on water management for food security. It has two purposes: to increase understanding of the current global status of research on water management for food security in developing countries and to analyze what it would take to develop a truly global and comprehensive partnership for research in this area.

The chapter begins by outlining the scope of research on water management and describing the actors that currently contribute to such research. It then presents a vision of what a truly global research partnership might look like, and analyzes the characteristics of the current global "system" of research on water management in relation to that vision. Finally, the chapter concludes with several recommendations for action to bring about this vision of an effective global partnership for research on water management.

The Scope of Research on Water Management for Food Security

The subject of water management for food security in developing countries is exceptionally broad. It encompasses, at one level, a variety of technical, economic, environmental, social, and institutional issues related to the use of water in the production of food—not only in irrigated areas but also in rainfed areas. At a second level, however, the subject encompasses a whole host of broader issues. This set of broader issues reflects two facts:

- that water has multiple functions and contributes to food security not only through food production but also through providing livelihoods for the poor and improving health conditions;
- that growing competition for water for other uses such as industry means that the management of water for agriculture must be analyzed in the context of water management as a whole.

For this reason, any discussion on research on water management for food security must begin by defining the scope of such research. This is not as straightforward as it is in other fields, since there is as yet no widely accepted and proven research paradigm for research on water management similar to that available for increasing the productivity of crops, for example (Petit 1994). Nevertheless, for the purposes of this chapter, some sense of the scope of research on water management can be gained by examining the eight highly interrelated areas that are enumerated in box 1. These subjects cover the vast majority of the technological, managerial, and policy questions to which decision makers engaged in water management to improve food security in developing countries are most urgently seeking answers.

In the remainder of this chapter, the term "water management research" is used as shorthand to describe all research addressing this broad set of issues.

Box 1. Key Topics for Research on Water Management for Food Security

1. Cropping systems: Covers the use of water and land resources for crop production. Key words include agronomy, cropping systems, farming systems, land development, land use, plant growth, soil-water relations, water requirements.
2. Economics and financial management: Covers economic and financial matters, including subsidies and their removal, cost recovery, pricing, resource mobilization, resource allocation, irrigation service fees, and finance. Key words include costs, economics, finance, investment, pricing.
3. Environment and health: Covers external (upstream and downstream) and within- system interactions with the environment. Key words include disease, health, ecology, environment, pollution, quality, water re-use, salinity, salt, waste water, watersheds.
4. Indicators: Covers the indicators that decision makers and users need to assess and improve performance. Key words include efficiency, performance, appraisal, evaluation.
5. Institutions: Covers the institutions that condition the legal, social, political, and economic environment and the organizations responsible for water management. Key words include governmental interrelations, institutions, legal aspects, legislation, privatization and turnover, politics, water rights, water markets, farmers, participation, water users' associations, organizations, bureaucracies.
6. Operations: Covers the operational management of water delivery and disposal— including water conveyance, allocation, distribution, and disposal—decision support systems, conjunctive use, and matching supply and demand. Key words include conjunctive use, models, operation, flow measurement, scheduling, simulation, delivery, distribution.
7. Technologies: Covers the physical infrastructure for water management and its renewal. Key words include construction, dams, design, engineering, equipment, hydrology, maintenance, modernization, pumps, rehabilitation, reservoirs, sprinklers, technology, wells.
8. Water resource policy and planning: Covers the management of water resources as a whole; national, provincial, and river basin planning; competition and linkages among sectors; comprehensive resource assessments; policy formulation and analysis; and strategic development. Key words include assessments, hydrology, intersectoral analysis, plans, policies, river basin, strategies.

The Vision of a Global Research Partnership

In outlining a broad vision of the characteristics that a global partnership for water management research should have, it is best to start with the vision for an agricultural research partnership that was laid out by many speakers at the Global Forum on Agricultural Research referred to earlier. In particular, the *Declaration and Plan of Action* adopted by the forum spelled out many of the elements of such a vision, such as the idea that a research partnership should be governed by principles of subsidiarity, participatory decision making, complementarity of efforts, adaptability, and openness (CGIAR 1996). And the CGIAR chairperson emphasized that in an effective global partnership, all actors would need to interact with one another in synergistic ways, with each actor contributing to the best of its comparative advantages, so that the whole is much more than the sum of the parts (Serageldin 1996).

Clearly, a global partnership for water management research should have at least the characteristics listed above. However, if this partnership is truly to address the enormous challenge of improving food security in the face of the growing scarcity and deteriorating quality of fresh water supplies, the vision needs to be expanded to embrace five additional elements:

- The total level of effort must be commensurate with the importance of the topic in achieving food security for the world's poor.
- All actors—from national, regional, and international centers and advanced research institutions, to nongovernmental organizations, universities, the private sector, community groups, and farmers—must be recognized as having the capacity to make an effective contribution to the overall research effort.
- The overall research effort must address all key research subjects, without major gaps in subject coverage, while at the same time giving particular attention to those topics that have the greatest impact on achieving food security for the poor.
- The research effort as a whole must be geographically equitable, while giving particular attention to those countries and regions where effective water management has the greatest impact on achieving food security for the poor.
- The research effort as a whole covers the range of strategic, applied, and adaptive research, giving attention to both the issues of today as well as the issues of tomorrow.

When contrasted to this vision of a global partnership, the current global research system has severe shortfalls. The extent to which current reality differs from the vision is analyzed in the following two sections. We start with a brief overview of the set of actors that are engaged in water management research.

Organizations and Groups Engaged in Water Management Research

As indicated earlier, a great variety of national, regional, and international organizations and groups are engaged in research that aims to contribute, in one way or another, to addressing the set of research issues outlined above. However, not all of these actors have the capacity to make a strong contribution to the overall research effort.

At the *national* level, water management research in developing countries in which the irrigated area is relatively limited is usually carried out by governmental agricultural research organizations—the national agricultural research systems (NARS), in the narrow sense of the term. In developing countries with significant irrigation, the NARS generally include a much broader range of actors, including not only governmental agricultural research organizations but also universities and specialist research organizations dealing with irrigated agronomy, water resources, and the social and management sciences, sometimes in collaboration with implementing agencies.

Also at the national level, but outside of the formal research establishment, considerable research and experimentation on water management for agriculture is carried out by nongovernmental organizations (NGOs), community groups, and farmers. In South Asia, for example, several leading NGOs, such as Proshika, the Grameen Bank, and the Aga Khan Rural Support Program, have pioneered methods for improving irrigation for the poor and engaging landless farmers in the ownership and control of irrigation facilities. And in many countries, there is a wealth of indigenous knowledge on traditional water management systems that in most cases has not been fully tapped; a recent study in India, for example, has documented the diversity of traditional water harvesting systems across the country (Centre for Science and Environment 1997).

Several national institutions in industrialized countries conduct research on irrigated agriculture in developing countries, usually in collaboration with national institutions in such countries under bilateral funding arrangements. Some of these research centers, located in countries with significant irrigation (such as the United States, Japan, and Australia), also carry out research on water management in their own countries. Advanced research organizations have also played prominent roles in major bilaterally funded irrigation projects in developing countries. Research under some of these projects (such as the Egypt Water Use and Management Project and its successor projects based at the Water Research Center in Cairo) has involved collaboration between developed and developing country researchers for a decade or more.

A modest amount of research is conducted by the private sector in some countries where there is major private-sector irrigation development, such as the United States or Brazil. Some specialist consulting firms also participate in bilaterally funded water management research programs.

At the *regional* level, several organizations are conducting water management research, although the geographical coverage is uneven. In Latin America, regional institutions engaged in water management research include the Inter-American Institute for Cooperation on Agriculture (IICA), the Tropical Agronomical Research and Higher Education Center (CATIE), and the International Center for Integrated Development of Land and Water (CIDIAT). The Mediterranean Agricultural Institute at Bari, Italy, conducts research relevant to the Mediterranean countries in Southern Europe, West Asia, and North Africa; whereas, in sub-Saharan Africa two regional organizations, Comite Interafricain d'Etudes Hydrauliques (CIEH) and Ecole Inter-Etats d'Ingenieurs de l'Equipement Rural (EIER) (both based in Burkina Faso), have done some work on water management. An attempt to establish a regional institute for water management research in Southeast Asia was promoted in the early 1980s, but failed to get off the ground.

At the *international* level, most institutions directly conducting research on irrigated agriculture lie within the CGIAR. The International Irrigation Management Institute (IIMI) is viewed as the lead center in the CGIAR for water management research; its mission is to create sustainable increases in the productivity of irrigated agriculture in the context of water basins and the analysis of water resources as a whole. Other CGIAR centers engaged in water-related research include the International Rice Research Institute (IRRI), the West Africa Rice Development Association (WARDA), the International Center for Agricultural Research in the Dry Areas (ICARDA), and the International Food Policy Research Institute (IFPRI). IIMI and several of these CGIAR centers have recently initiated a "Systemwide Initiative on Water Management Research," carried out in collaboration with several non-CGIAR institutions.

Several international programs also play major facilitating roles in water management research. The International Program for Technology Research on Irrigation and Drainage (IPTRID), which is currently a part of the World Bank but which at the time of this writing is discussing a change in its institutional arrangements, assists countries in identifying research priorities, preparing research project proposals, mobilizing resources for funding, and disseminating lessons learned in the areas of modernization, maintenance, and sustainability. FAO's International Action Program on Water for Sustainable Agricultural Development (WASAD) assists countries in the application of research results through demonstrations, technology transfer, and other activities. And the International Commission on Irrigation and Drainage (ICID) has had a long-standing interest in irrigation and drainage research and is a cosponsor, along with UNDP and the World Bank, of IPTRID.

Shortfalls of the Current System

Taken as a whole, the set of national, regional, and international research institutes and programs described in the previous section can be viewed as a worldwide "system" that is conducting a wide variety of research activities on a multiplicity of subjects, in a variety of countries, and employing various methodologies and approaches. However, as alluded to earlier, this "system" is still very far from achieving the vision of an effective global partnership for water management research. Some of the ways in which it differs from the vision are discussed below.

1. The total level of effort and resource allocation is low in relation to the magnitude of the problem and in comparison with other areas of agricultural research.

   The extent of this problem is difficult to quantify accurately, since no systematic survey of ongoing research has been conducted to date. Even the total level of funding is not known with any degree of precision. However, on the basis of some early estimates developed at the time that IPTRID was established (UNDP/World Bank 1990), it is likely that current expenditures on all kinds of water management research aimed at developing-country issues are not much more than some US$ 150 million a year.

   Clearly, therefore, the resources available for water management research are meager in relation to the total investment requirements for all aspects of water resource management, which have been estimated by the World Bank to be on the order of US$ 600 billion to US$ 800 billion during the next decade, and which do not compare favorably with the resources available for agricultural research more broadly, which exceed US$ 6 billion worldwide. Without a doubt, the Committee on Agricultural Sustainability for Developing Countries (CASDC) is right in concluding that "research on water resources management and irrigation has continued to be the orphan of the research community" (CASDC 1995).

2. Most national research systems do not yet have the capacity to make a strong contribution to the overall research effort.

   Although national institutions involved in water management research in developing countries are critical to the development of effective water management practices at the national and local level, they are at present unequal partners in the total research effort. Indeed, as CASDC (1995) has pointed out, most national research systems have yet to develop the necessary strength to address the expensive and complex research issues involved in water management—and are struggling to maintain financial and political support. Four particular dimensions of the weakness of national institutions need to be highlighted.

   First, funding for research at the national level is disproportionately low. Of the total annual expenditures on water management research of US$ 150 million a year, perhaps only US$ 90 million per year is allocated for research conducted by national institutions in developing countries. And although hard figures are difficult to come by, it appears likely that the non-CGIAR or CGIAR-related institutions account for only 90% of total expenditures in water management research—as opposed to 96% in agricultural research more broadly.

Second, several developing countries with substantial irrigation have almost no capacity to conduct research to improve the performance of their irrigated agriculture. And major countries with important irrigated agricultural sectors, such as Iraq or Iran, remain largely disconnected from the work of IIMI, IPTRID, and other international or regional research organizations.

Third, even in those countries where significant water management research is underway and where linkages with the international system have been well established, national scientific capacity to conduct research on water management is frequently weak and fragmented. As IIMI (1992) has highlighted, national capacity for water management research is much weaker, in general, than national capacity in crop production and other areas of agricultural research.

Finally, although there have been significant institutional developments on the international front during the last decade, there has not been anything near the same amount of institutional change at the national level. Most of the major national research centers were established two or three decades ago; in the last 10 years, only one new national research center (the Mexican Institute of Water Technology) has come into existence, although plans in some countries have been formulated.

3. The set of national, regional and international actors engaged in water management research do not yet operate as a system in any true sense of the word.

In part because it has evolved in a piece-meal fashion, the global system in place for research on irrigated agriculture is fragmented and dispersed. To a large extent, participating research institutions do not build on the findings of others. Examples of effective collaboration are few. Opportunities for linking researchers in different institutions and countries are limited, and the potential of the information revolution to link researchers working on common themes in different locations has not yet been fully exploited. For this reason, few would disagree with the assessment of the external review panel of IIMI (CGIAR 1994) that the existing worldwide irrigation research institutions "do not presently constitute an integrated community by any means."

Overall, the usual mechanisms to improve linkages among researchers have only been moderately effective. Although several information networks on water management (including, in particular, those organized by the UK's Overseas Development Institute and by IPTRID) have been quite successful, the development of *research* networks in water management has been neglected. Insufficient journals widely read within the water management community exist to allow researchers to share their ideas with one another (although *Irrigation and Drainage Systems* has played an increasingly important role in this respect since its establishment in 1986). And although the information revolution has led to enormous potential for linking researchers and for providing researchers around the world with instant access to information on scientific developments, this potential has not yet come close to its full development.

Furthermore, although the ICID, especially through its research committee, has played an important role in bringing together researchers and practitioners engaged in technological research on irrigation and drainage, there is not as yet a professional association to bring together all those engaged in broader aspects of research on water management for food security. And no association of water management research institutes—along the lines, say, of the International Union of Forestry Research Organizations (IUFRO) in the field of forestry research—has yet been organized.

4. Current research is not conducted in all the highest-priority countries and regions, and there are major gaps in geographic coverage.

A study of the current literature on water management research, commissioned by the author in 1995, which reviewed in detail the research conducted in or on the 16 countries whose irrigated area exceeds two million hectares—India, China, the US, and Pakistan (each of which has more than 10 million hectares), followed by Indonesia, Iran, Mexico, Iraq, Turkey, Thailand, Egypt, Japan, Afghanistan, Brazil, Bangladesh, and Sudan—has shed some light on this issue. In particular, the study revealed the following:

- Published research on India far exceeds that relating to other developing countries. China and Pakistan, both of which have extensive irrigated areas, lie far behind India in this respect.
- Two countries with significant irrigated areas—Egypt and Bangladesh—also appear to be relatively well endowed with results on water management research, followed by Indonesia, Mexico, Thailand, and Brazil.
- Five developing countries with significant irrigated areas—Iran, Iraq, Turkey, Afghanistan, and (to a lesser extent) Sudan—appear to be significantly underrepresented in the literature. Not surprisingly, these countries do not have strong national research systems for water management, nor an active presence of international research organizations (although the recent initiation of an IIMI program in Turkey may change the picture in that country).

5. The global system of water management research as a whole contains some incongruities in mandates, and there are major gaps in subject coverage and understanding.

This problem is difficult to pinpoint in the absence of a comprehensive review of worldwide research on water management. However, two specific areas of concern are apparent.

First, as most observers would agree, since each component of the global irrigation research system has been created relatively independently in response to specific national and international needs, the system as a whole is bound to contain gaps and overlaps. At the national level, mandates often focus on technological issues, thereby neglecting social, economic, environmental, and institutional subjects. And at the international level, no institutions currently have a clear mandate either for strategic research on irrigation technology or for strengthening national policy and management research by developing countries.

Second, although globally there do not appear to be any major absolute gaps in broad subject-matter coverage, there are clearly gaps in research *within* some of these priority areas. For example, a detailed bibliographic search commissioned by the author in 1995 revealed that relatively little current research on institutions focuses on the management of public organizations (despite their predominant role in most major irrigator countries), and relatively little current research on technologies focuses on technologies for small-holder irrigation in developing countries. The search also confirmed that technologies, operations, and cropping systems have received the greater share of research attention to date—an emphasis that is clearly reflected in the subject-matter content of the main research journals to which water management researchers contribute. Most researchers doing work on nontechnical dimensions of water management appear to publish in journals outside the classical "water management" domain.

6. Current research is insufficiently addressing the problems of tomorrow. This problem can be analyzed by classifying water management research in terms of the CGIAR categories of strategic, applied and adaptive research (see box 2). By and large, strategic research, aimed at the discovery of principles or new knowledge, is future-oriented, whereas applied and adaptive research help address current problems. For example, if it is accepted that the world needs to find ways to operate irrigation systems more efficiently, then a deep understanding of the cause-and-effect relationships within operating irrigation systems is needed. Strategic research would be aimed at developing this understanding; whereas, applied and adaptive research would develop specific approaches that

Box 2. Strategic, Applied, and Adaptive Research in the Context of Water Management irrigation managers can put into effect, based on the conceptual understandings derived from strategic research.

Judging from the current literature on water management research, it appears that a majority of current research on water management is either applied or adaptive. A survey of seven issues of *Irrigation and Drainage Systems* over a two-year period, for example, revealed that less than a third of its contents could be truly characterized as strategic research—i.e., that the research was aimed at generating improved understanding in a subject of strategic importance, either to the country in which the research was conducted or more generally. Similar surveys of other journals, most of which are more applied in nature than *Irrigation and Drainage Systems*, would likely show an even smaller proportion of publications based on strategic research.

The fact that most current research is applied or adaptive is not, in itself, surprising. However, it is cause for concern, since it indicates that the water management research community is not adequately preparing for the future and, in particular, the future challenge of increasing food security overall in the face of sharply declining supplies of fresh water.

Recommendations for Change

Clearly, the picture that emerges from the preceding analysis suggests that the current status of global research on water management differs quite substantially from the vision of a global partnership that was laid out earlier. Although a wide range of actors are contributing to the overall research effort in a number of different ways, the total level of effort is *not* commensurate with the importance of the topic, the actors are *not* interacting with one another in the most synergistic manner, and the research effort is *neither* geographically equitable nor giving adequate attention to the issues of tomorrow. Overall, from a variety of angles, “what is” is quite different from “what could and should be”. Some reflections on these shortcomings and on what can and should be done are given below.

First, in view of the serious weakness of national research systems, governments and external assistance agencies must give concerted attention to strengthening national capacity for water management research. International institutions that conduct water management research must continue to play an important role in strengthening national water management research through collaborative-research and other institution-strengthening activities. Given the absence of national research systems in a number of countries with significant irrigated areas, the international community must find ways to put these countries on the water management research map and to assist them in developing and strengthening their national water management research systems. And further progress should be made to accelerate the use of loan funds for national water management research.

Second, special attention needs to be given to human resource development for water management research. As noted by the UNDP/World Bank (1990), successful research depends on the number, orientation, and quality of water management specialists involved in water management research in developing countries. For this reason, institutional development programs aimed at assisting developing countries in building scientific capacity in their national research systems should be accorded priority. Efforts to create linkages with universities, advanced institutions, and international centers should be strengthened. And national research systems should be encouraged to utilize the approaches and methodologies most conducive to high research productivity, taking into account the lessons currently being learned by IIMI and other advanced research institutions.

Third, specific measures must be taken to help forge partnerships among the national, regional, and international institutions that are currently engaged in research on water management in developing countries—for example, by promoting the development of research networks, establishing some form of association of research institutes, encouraging and supporting the important work currently played by professional associations such as ICID, and increasing the number and quality of journals to communicate research results within the irrigation community. It is important for the most advanced institutions to take the lead in using modern communication technologies to demonstrate the potential of the information revolution for linking researchers in different locations working on common themes, as IIMI is doing through its "virtual institution" initiative.

Fourth, IIMI, IPTRID, and FAO should set the example for effective partnerships at all levels by developing a far-reaching coalition at the international level. A global alliance among IIMI, IPTRID, and FAO could unleash enormous synergy—with IIMI spearheading strategic research on key topics in water management research, IPTRID taking charge of services to help strengthen national research systems, and FAO taking the lead in translating research results into solid on-the-ground technical assistance to developing countries. If a true IIMI/IPTRID/FAO partnership could blossom, much else could follow.

Fifth, research administrators and program leaders, at both the international and national levels, must ensure that the subject-matter coverage of their research programs responds to national, regional, or global priorities. For this reason, mechanisms must be found to ensure that research is demand driven and allocated to the areas where the potential for impact is the greatest—which in turn will require both developing better and more quantitative methods for research priority-setting and ensuring that priorities are set with the active involvement and participation of research users, so that research priorities are demand driven and forward looking.

And finally, ways must be found to substantially increase the resources allocated to water management research. Despite the many significant institutional developments that have taken place on the water management research front over the last decade, the simple fact remains that total expenditures for research on water management in developing countries are only 1% of the total annual investment in irrigation and drainage worldwide—and much, much less than 1% of the total production value of irrigated output. This is a drop in the ocean in relation to the magnitude of the challenges that lie ahead—and cannot be accepted if these challenges are to be seriously addressed.

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Wild Biodiversity: The Last Frontier? The Case of Costa Rica

Nicolás Mateo

The management and expansion of the agricultural frontier has brought mixed blessings to Costa Rica. On the positive side, it has promoted democracy, national values, and political stability, and it has been the key ingredient of the economic development model during the last century and a half.

On the negative side, agricultural expansion has resulted in poor management of the natural resources in most of the country and very low value-added, and it has created a dangerous dependence on a small number of crops.

The agricultural sector, while still contributing about 17 percent to the GNP, is currently undergoing a severe identity crisis caused by the shifts and pressures of globalization and fluctuating, but ever-falling export prices. A few successful exceptions include niche export markets for high-value vegetables, fruits, and ornamentals, which have brought the country competitive advantages.

Research is a true reflection of the overall picture of the agricultural sector. It has generated or imported a number of useful technologies, contributed to national food security, and developed successful research systems on a few selected crops such as coffee. At the same time, however, Costa Rica's national research strategy, particularly in the early days, adopted and adapted crop and animal production systems not suited to its highly variable tropical environments. Agricultural research has attempted to maximize production at any cost, using a model based on high inputs that cause pollution and contamination of land, water, and animal life.

It is essential that we learn from agricultural history in order to conserve and use wild biodiversity (which is certainly the last R&D frontier) intelligently. There are fundamental criteria to achieve this goal, most of them clearly spelled

Although this paper does not directly address the topic of this book, the editors felt that it was an important case study that should have wide distribution. A shortened version of the original paper is therefore included here to underline the importance of this subject, to introduce this promising new approach, to highlight the issues involved, and to emphasize the benefits to be derived for future global agricultural research from the kinds of broad linkages and interactions (with many different partners, including education and the public) used in this approach.

out in the tenets of the Biological Diversity Convention. These include access, equity (including research income and royalties allocated for conservation), transfer of know-how and technologies, and advanced training of national scientists. Other criteria are value-added strategies, negotiating ability, an understanding of the markets, and development of strategic alliances with universities, research centers, and industry.

The National Biodiversity Institute

On the basis of existing parallels in the agricultural sector that emphasize the need to add as much value as possible to biodiversity in genetic resource-rich countries, this paper will describe and discuss some experiences and lessons from the Instituto Nacional de Biodiversidad (INBio) in Costa Rica.

Approximately 25 percent of Costa Rica's territory consists of wildlands conserved for their biodiversity and containing approximately half a million species of animals, plants, and microorganisms. These organisms are distributed from the nearly desert-dry forest habitat of the northwest to the very wet rainforest habitats of the remainder of the Costa Rican lowlands, and the mountain ranges that are over 3000 meters high. This biodiversity—representing four to five percent of that of the terrestrial world—is a major renewable resource and a potentially powerful engine for Costa Rica's intellectual and economic development.

In 1988, a national planning commission established by executive presidential decree recommended that INBio be created as a nonprofit, nongovernmental organization for the public good. INBio was legally registered in 1989 and is governed by an assembly of founders and a board of directors. This legal structure has enabled INBio to satisfy the need for flexibility in handling the rapidly expanding field of biodiversity management. All of INBio's activities involve close integration with both public and private institutions (domestic and international) and are conducted under the assumption that society will conserve a major portion of its wild biodiversity only if protected areas can generate ample intellectual, spiritual, and economic benefits. INBio, based on a legally established partnership of cooperative support with the Ministry of the Environment and Energy, carries out the following processes in order to fulfill its mission of conserving, knowing, and using Costa Rica's biodiversity in a sustainable fashion:

- a biodiversity inventory, with emphasis in Costa Rica's national protected areas *(National Biodiversity Inventory Division);*
- transfer and dissemination of biodiversity knowledge *(Biodiversity Information Dissemination Division);*
- organization and administration of biodiversity information *(Biodiversity Information Management Division);*
- the search for sustainable uses of biodiversity by any and all sectors of society, and the promotion of these uses *(Biodiversity Prospecting Division).*

The National Biodiversity Inventory

INBio's National Biodiversity Inventory builds on a long history of specialized national and international taxonomic research of Costa Rican fauna and flora. It initiated its activities focusing on a limited number of taxa (plants, insects, mollusks, and fungi) in 1996. The field work for the inventory is being conducted by a small army of lay people trained in the vocation of the "parataxonomist." The parataxonomist is not merely a collector, but is also the initial cataloguer of specimens and serves as a direct link to the communities that live in and around the Costa Rican wildlands.

Parataxonomists bring their collections to INBio on a monthly basis, at which time technicians label, process and prepare the material for taxonomic identification by curators. Parataxonomists and technicians receive feedback, planning support, and guidance from INBio's curators, who work within a larger network of national and international taxonomy experts. The goal is to generate properly identified reference collections and field guides and to provide electronic identification services that add knowledge about the organisms' natural history and document their distribution throughout the national territory.

The results are impressive. The Inventory Division has 31 biodiversity offices in the various conservation areas, where 45 paratoxonomists are stationed. The process includes 18 curators, 12 technicians, 4 labelers, and a number of visiting foreign taxonomists (53 in 1995). In addition, 373,000 entomological specimens were collected in 1995, increasing the reference collection to over 2.5 million insects in 1995. Of these, 2.1 million have been labeled, and 384,000 identified to the species level. Bryophyte specimens numbering more than 1,000 were also added to the collection, while the taxonomy of plant species, estimated at 12,000 is almost completed, even though 43 new species of plants were described and 26 others were new records for Costa Rica. The malacology collection now includes 45,000 specimens of which 6,600 have been classified to the family level, 16,400 to the genus, and 21,800 to the species level. At least eight are new species for the world and approximately 20 are new records for the country. Finally a mycology department was opened in 1995 to inventory macrofungi as the basis for exploring potentially useful bioactive substances.

Within the Inventory Division, the All Taxa Biodiversity Inventory (ATBI) is a unique and ambitious initiative taking place in the Guanacaste Conservation Area to document its estimated 230,000 species. The project is based on direct support from various agencies and governments (NSF, NORAD, GEF and the Dutch Government), and will include the expertise of about 300 national and internationally renowned taxonomists.

To date, the ATBI, in preparation for the project's full implementation, has organized eight workshops with national and international participants to agree on protocols and strategies for the different taxonomic components.

Biodiversity Information Dissemination Division

In order to spread biodiversity literacy rapidly and generate an appreciation of what biodiversity information can offer, INBio's Biodiversity Information Dissemination Division is developing methods to actively distribute biodiversity information to all levels of society. This distribution comes about through offering natural history and taxonomic information to schools and universities, disseminating information about the commercial possibilities of conserved wildlands, working with legislators, participating in policy-making commissions and symposia, training Conservation Area staff, producing hard copy field guides and other types of biodiversity literature, holding national and international workshops, and much more. The Division is promoting the development of a society whose ethical and moral values are rooted in respect for nature and the wise management of natural resources.

As part of this, in 1995, an educational project, the Biodiversity Education Program, was developed for two local primary schools to provide information on biodiversity conservation and sustainable development. INBio's educational activities have also caught the interest of the Ministry of Education, which wishes to incorporate elements of biodiversity management in the national curricula.

Biodiversity Information Management Division

INBio has been described, quite rightly, as an information management organization. The amount of information on biodiversity (specimen data, literature, and field data) is rapidly growing, and when coupled with relevant support information such as topographic maps, soil maps, climate data, land use, and much more, the data package becomes extremely complex. This information requires a capacity of analysis, management, presentation, distribution, and integration not yet achieved by any set of biodiversity users in the world. INBio is bringing cutting-edge technology in database management and development to bear on this challenge. The Division is currently active in six main areas:

- The Biodiversity Information Management System (BIMS). The BIMS already includes all information generated by the arthropod department. The botany, malacology, and mycology databases are soon to be integrated.
- Geographic information systems. A series of aerial photographs of the Osa and Amistad Conservation Areas have been accumulated as well as photogrametric maps with valuable political and administrative information.

- Multimedia. The Electronic Atlas for Agenda 21 (ELADA 21) is a multinational project sponsored by IDRC (Canada) to include information on environmental issues that permits social and economic interpretation, among other analyses.
- Internet. Electronic mail is used in INBio on a daily basis and more than 9,000 screens with general and specific information have been produced for INBio's World Wide Web site. In partnership with the Missouri Botanical Garden, an electronic version of the Manual of Costa Rican Flora can be viewed on the site.
- Biodiversity prospecting database. The increase in computer capacity, coupled with the integration of the BIMS and GIS, allows better handling of the data and more reliable information.
- Biodata. A new project for assistance in building Costa Rica's capacity to manage biodiversity data and to network was initiated in collaboration with UNEP.

The Biodiversity Prospecting Division

The search for new organic chemicals and genes is essential to INBio's efforts to conserve biodiversity. At present, these efforts are focused on the search for chemicals produced by plants, insects, and microorganisms that may be of use to pharmaceutical, medical, and agricultural industries. In this context, the role of the "bioprospector" is essential. Working closely with the paratoxonomists, the bioprospectors follow biological leads, contribute to the natural history of potentially useful organisms collected and add key information to the databases. The bioprospectors collect "prospectable" specimens (sampling that will neither destroy nor promote genetic erosion) and make sure that nondamaging resupply is possible.

Prospecting and research processes are carried out in collaboration with local and international research centers, universities, and the private sector. The set of criteria used by INBio to define its research agreements in 1991 was ahead of its time and includes key elements (access, equity, transfer of technology, and training) that were later agreed upon at the UNCED meeting in Rio de Janeiro in 1992. Agreements stipulate that 10 percent of research budgets and 50 percent of any future royalties be awarded to the Ministry of the Environment and Energy (MINAE) for reinvestment in conservation. The remainder of the research budget supports in-country scientific and processing infrastructure and value-added activities, also oriented to conservation and the sustainable use of biodiversity.

INBio's strategy has focused on developing a diversified portfolio of bioprospecting research agreements that foster innovation, learning, and local capacity building. Some of the ongoing agreements are briefly discussed below:

- Academic research agreements with Costa Rican universities. (Universidad de Costa Rica, Universidad Nacional) and foreign universities

(Strathclyde, Dusseldorf, Laussane, etc.). These agreements vary considerably in scope but all of them are problem oriented and search for new knowledge and products. The agreement with the University of Costa Rica, for example, allows for collaborative research on malaria as well as extremophilic organisms (archaebacteria) living in hot volcanic springs.

- Chemical prospecting in a Costa Rican conservation area. One of five international cooperative biodiversity groups (ICBGs) in the world, this project is carried out in the Guanacaste Conservation Area in collaboration with the University of Costa Rica, Cornell University, and The Bristol Myers Squibb Company. The project's aim is to obtain potentially useful substances from tropical insects and upgrade human resources in the fields of ecology, taxonomy, and ecochemistry.
- INBio-Merck agreement. Considered a landmark, the INBio-Merck project has fully integrated the issues of access, equity, technology transfer, and capacity building into one single agreement. The project searches for new pharmaceutical and agricultural products from plants, insects, and environmental samples. The first agreement was initiated in 1992 and renewed in 1994 and again in 1996. Promising results on the biological activity and characterization of chemical compounds have been obtained.
- Antimicrobial and anti-viral activity from natural compounds. This is a new agreement signed with the phyto-pharmaceutical company INDENA from Milano, Italy. It provides the opportunity to conduct considerable value-added research, including new bioassays and research on microorganisms.
- New fragrances and essences for cosmetic and household purposes. This is a small and innovative agreement with Givaudan-Roure Fragrances of New Jersey, which aims to identify and collect interesting odors from the airspace near fragrant forest organisms.
- DMDP. A nematicide obtained from *Lonchocharpus* sp is currently being studied for domestication, extraction, and field evaluation under an agreement with the British Technology Group and Ecos La Pacifica, in collaboration with the Costa Rican Banana Corporation, Kew Botanical Gardens, and the Guanacaste Conservation Area. This is a promising environmentally friendly, cost-effective research and development initiative, given the high environmental and financial costs associated with the application of synthetic nematicides to tropical crops.
- Potential industrial use of extremophilic organisms. In collaboration with Recombinant Biocatalysis Co. of California, INBio is studying microorganisms that thrive in extreme pH and/or temperatures in the search to clone DNA sequences for use in bioremediation and industrial processes. This collaborative research is carried out in conjunction with the University of Costa Rica's Center for Cell and Molecular Biology.
- Investment agreement with the Government of Canada. The governments of Canada and Costa Rica reached a debt-for-nature swap agreement that provides support for the "Biodiversity and Socio-Economic Development Project," an initiative for sustainable use of the country's

biodiversity resources. It also contributes to INBio's consolidation. The project supports the development of intellectual and industrial uses of biodiversity and INBio's endowment fund for 1996-2000.

What Factors Are Responsible for INBio's Success?

The overall goals of INBio have been stated as saving, knowing, and using biodiversity for the benefit of society. There are many reasons why INBio has been not only a viable organization, but also a world leader in the context of the Biodiversity Convention. The following aspects are the most relevant ones:

- **The right circumstances at the right time.** The political, scientific, and socioeconomic environment was ripe in 1989 for creating a flexible association closely linked to the government, to assume responsibility for the national inventory and other biodiversity management activities.
- **Political support.** INBio, given the high priority assigned by all sectors of society to biodiversity management, has been fully supported by the various political fractions and different administrations.
- **Leadership and vision.** INBio's founders had a very clear vision and mission in mind and have been able to inspire and maintain leadership.
- **A commitment to innovation.** There were no models and no significant pilot projects to learn from. Therefore, new concepts such as parataxonomists, databases and data systems, prospecting agreements, bioliteracy campaigns, and other ideas have had to be developed on a continuous basis.
- **A diversified portfolio.** INBio has worked and experimented with various research agreements and R&D modalities to fulfill its mission. It is a learning institution par excellence.
- **Strategic alliances.** INBio recognized its own limitations and the need to avoid costly duplication from the beginning. A key strategy has been forging alliances locally and internationally with the government, academic, research, and private sectors in order to maximize resources and catalyze processes.

Other Initiatives and Remaining Challenges

The rapid, worldwide loss of biodiversity we see today is a consequence of the destruction of tropical forests and water resources. As a result, conserving biodiversity is tightly linked to the maintenance of forestry and reforestation programs. Although Costa Rican forests are well protected as government-sheltered conservation areas, only 180,000 hectares of privately owned forests remain. Financial incentives must be provided to private land owners to stimulate reforestation. Unchecked logging often leads to monocultures, decreased biodiversity, and other negative ecological impact. Further incentives are required to cultivate mixed stands on private lands. It is INBio's goal to couple these reforestation programs with the conservation and regeneration of biodiversity in order to create stable ecosystems with multiple uses. It is important to note that carbon sequestration is only feasible in deforested areas, ecotourists will prefer certain regions, hydroelectric power can be only generated in regions of high altitude, and logging requires forests to be easily accessible.

- Carbon sequestration. The first indications of global warming led to hectic activities worldwide to reduce the emission of CO_2 and provide additional CO_2 sinks. The dense biomass in tropical forests has the capacity to bind about 150 tons of CO_2 per hectare. Worldwide, companies with high CO_2 emissions are therefore considering funding reforestation programs in the tropics for carbon offset. The international market for carbon sequestration is just evolving and the final price for each ton of fixed CO_2 will ultimately depend on supply and demand and the magnitude of the economic damage that can be avoided by this measure.
- Sustainable logging. Production of wood, paper, paper pulp, and fire wood is still the most economically important use of forests. Sustainable logging systems must avoid monocultures, and local tree species have to be cultivated to regenerate stable and diverse ecosystems.
- Existence and options. Values are generated by national and international funds (such as the World Wildlife Fund) to finance the conservation of protected areas. They simply reflect the price the world is willing to pay to maintain tropical forests and their biodiversity.
- Ecotourism. The value of ecotourism is based on an analysis of tourist expenditures in the Monteverde Natural Reserve.
- Hydroelectric power and urban and rural water supplies. The values depend on the function of the forest as a water reservoir. Further values could be added for other functions, e.g., flood control.
- Prospecting for new pharmaceuticals. The value of prospecting for new pharmaceuticals is based on the following assumptions made by Mendelsohn and Balick (1995): with 5.8 percent of the world's tropical forest species of higher plants, Costa Rica should also have 5.8 percent of the undiscovered drugs from tropical plants. If Costa Rica were to prospect its botanical diversity with one company only, this search would probably yield two to three new drugs. Prospecting from plant diversity with more than one company would increase this value respectively. Evaluation of further organisms like insects, molluscs, fungi, and bacteria will further increase the pharmaceutical value to a degree where it becomes compatible with other uses.

The overall value of 1.3 million hectares of Costa Rican tropical forests is estimated at US$182 million per year. In comparison, Costa Rica's annual income from meat exports in 1994 yielded US$32 million (Costa Rican Export Directory, 1995). To achieve this export volume, about 1.2 million hectares of tropical forest were turned into pasture land from 1943 to 1987!

The benefits from conservation areas can also be projected to adjacent agricultural lands (buffer zones). Ongoing research in northern Costa Rica attempts to evaluate and measure the positive impact of conservation areas on orange plantations in regard to biocontrol and water accessibility. Results are not yet available.

Further values can be expected from nonwood products like nuts, fruits, ornamental plants, fibres, oils, phytopharmaceuticals, and meat and leather from wild animals, which could be produced more economically in a forest than by domestication. Some of these products are already on the market, like the medicinal plant *Smilax* sp. However, these products are collected in a nonsustainable way, which has already led to species extinction in certain regions. More innovative approaches and research are required to establish sustainable techniques for collection and cultivation in the forest and to develop new products for the international market.

A Final Word

The rapid globalization of economies and the sciences, and the implications of the Convention on Biological Diversity, will bring profound changes in the way research and development on agricultural and wild biodiversity takes place in the next few years. Local conditions and strategies will continue to exert a great influence; however, a global scene where bilateral and multilateral agreements and strategic alliances take place will be influential factors in conserving and making use of biodiversity.

While not a model for all nations, the experiences and results obtained by INBio can provide an example from which several lessons can be drawn:

- Society will be interested in conservation only if it perceives that clear spiritual intellectual, and economic benefits can be derived from biodiversity.
- The operational flexibility of a private organization with full government backing permits rapid advancements in biodiversity management.
- Value-added, negotiating skills, national capacity building, and innovation are the key ingredients for success.

Mesoamerica has been the cradle of many agricultural crops, some of them of world importance, like maize and common beans. These crops were domesticated from wild relatives found in fast-disappearing regional forests. New genes, new crops, new pharmaceutical and agricultural products constitute the last frontier of wild biodiversity. It is our responsibility to guarantee its intelligent use for the benefit of following generations.

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Implications of Trade Globalization to Agricultural Research

John W. Mellor

The steady march of trade globalization is now irreversible, because nowadays it is so much technology- rather than politics-driven. Since politics slows the impact of technology on trade, adjustments do occur gradually but are not reversed or even stopped. The steady globalization of trade has four profound implications for agricultural research in developing countries.

> First, production of high-value agricultural commodities, such as horticultural products, can now expand much more rapidly than domestic demand. That means that these commodities can play a role in intensifying production, with immense direct benefits to growth, the environment, the poor, and to women, right from the start of development, even before rising per capita incomes drive domestic demand. This is a major change from the development environment for poor countries of even a few decades ago. The most important impact is in making possible growth rates in agriculture that are a percentage point or two faster than what could be achieved only a few decades ago. That, in turn, has profound implications for poverty reduction, the environment, and the empowerment of women.
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> Second, a global market means that global quality standards must be met, at least on an income-specific basis that applies to both domestic and foreign markets. That is not just a marketing job, narrowly defined. It also means that production must be tuned to actual, rapidly changing product demand. Such adaptation to global markets requires state-of-the-art research, which can be achieved only by setting global standards of research, very narrowly defined priorities to allow concentration of resources, and close interaction with the private sector of farmers and marketers. No more than the tiniest handful of developing countries is set on that course. Most are far behind developed countries in narrowing their research through priority setting and in working with the private, commercial sector, even though they are increasingly coming into head-to-head competition with the more advanced countries.
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> Third, the potential for high-value commodities increases the returns to physical infrastructure development. On the one hand, that investment must be

made if the immense benefits from increased production of high-value commodities are to be fully realized. On the other hand, the payoff comes only in the regions and subregions where it has been made, demanding further prioritizing of research. The higher returns to investment in infrastructure, of course, greatly facilitate the geographic diffusion of development that is so important to easing the blight that arises from concentrating urbanization in the capital city.

Fourth, the CGIAR's concentration on food crops will now be done in an environment of increasing regional specialization and, with more rapidly rising rural incomes, increasing removal of land from agriculture. Thus, the geographic orientation appropriate to the past will provide lower returns to research than the new one appropriate to the future. Some ecological situations that would previously have produced cereals will now be abandoned from agriculture, others will be devoted to high-value noncereal commodities. Meanwhile, the area devoted to cereals will be smaller and more intensively managed.

Background

A paragraph explaining the source of these observations is in order. In the five years since I was director of one of the CGIAR centers, I have devoted myself to running a policy consulting firm working in developing countries, an entirely applied occupation. In that period, I have not set foot in a CGIAR center nor met a CG center director or developed-country donor or CG board member. The consulting work has always involved a careful look at the national agricultural research system and considerable interaction with CG scientists working with national systems and developing-country donors and CG board members. This has been done in 10 countries.

Thus, my observations come with an old knowledge of the CG system, a new knowledge of the national systems, and an applied perspective.

Globalization of Markets

The costs of providing specified product services to consumers is dropping, particularly with increasing fuel efficiency and decreasing cost of providing shipability, particularly through technological improvement. Consumer tastes are broadening as one of the many globalization features of the information age. Contrary to popular impressions, this is by no means a one-way flow from mature economies to the less mature.

As an example of these trends, an apple can be placed competitively by any producer in any market at any time of the year, and vastly more consumers have broadened their tastes to include apples. In any month, New Zealand apples are competitive in Washington, DC, with apples produced 60 miles away. That was not true a few decades ago. And yet, to continue the analogy, apple varieties being planted now in much of South Asia will not be able to compete with New

Zealand apples once South Asian markets open, because they will be within the production span of presently planted apples.

Developing countries are potentially low-cost producers of most high-value agricultural commodities, because of low labor costs and a wide range of suitable physical environments. But to compete effectively and to obtain maximum returns to their labor, they must produce the right commodity at the right time, including meeting complex health requirements. That is an ever-moving target, one that only a world-class research system can meet.

There is another effect of globalization of markets: commercial interests can find the necessary economies of scale in many more commodities and countries than previously. While national systems need to adjust to accommodate that interest, the economies of scale may allow commercial firms to engage in research and extension activities for their commodities, which can both save resources for developing countries and concurrently require them to take into account complementarities with commercial interests. Public and private research are increasingly complementary to each other rather than competitive. But to realize those economies for the nation requires a new outlook, and the precise form of those complementary activities will, of course, be quite different in a developing economy than in a more mature one, and will require considerable leadership and imagination. I see little of that kind of thinking in developing countries and tremendous change along those lines in developed countries.

The Agricultural Growth Rate

From the point of view of resource allocation, aggregate agricultural growth is best seen as the sum of component parts specific to commodities and geographic regions. The importance of a commodity and region is a function of its initial weight in the production system and its potential rate of growth. Of course, the weight of a given component will increase rapidly if the growth rate is high. Thus, aggregate growth is a dynamic process, and in making long-term investments, as in research, one must look at future weights and growth rates.

The high-value commodities, because of lower land constraints, can grow at eight to 10 percent per year—comparable to what is expected of the industrial sector—and have powerful multipliers on overall growth and employment. In the past, one of the major impediments to agriculture playing its historical role in growth and employment in other sectors has been the difficulty of matching the modern world's very high population growth rates with even higher agricultural growth rates. For example, it has been difficult, except for short periods of catch-up growth, for the basic cereals to grow in excess of three percent per year. That is little more than present population growth rates in low-income countries. At the time of Japan's modernization, a three percent agricultural growth rate would provide one and one-half to two percent per capita. For agriculture to play a major role in poverty reduction requires far higher growth rates than simply matching population growth with food supplies.

High-value commodities offer the opportunity for the aggregate agricultural growth rate to greatly accelerate from the historical level and thereby to substantially exceed the population growth rate. That is why emphasis needs to be given to technological advancement in those commodities and to providing the level of research support needed to achieve that goal.

Does this mean neglect for the basic food crops? Of course not. Food security still matters even in a trading world. Far more farmers will continue to gain the bulk of their income from cereals than from high-value commodities. Even with only modest growth rates, basic cereals still have a heavy weight in aggregate growth rates. But the research strategy for cereals needs to take these new circumstances into account.

For one thing, the priorities required for research on food crops are just as tight as those for high-value crops. Unfortunately, donors and the CG system tend to push individual poor countries into developing research systems for far more food commodities than they can support. Some of that is driven by a "food-first" type of mentality; some is driven by excessive emphasis on direct impact rather than indirect impact on poverty, nutritional status, and other ends of development.

Of course, the CG, servicing many countries, must cover more commodities than any one country. It is doubtful if the typical low-income country can afford a first-class research system for more than two or three food crops. Who will help set those tight priorities? Will donors push countries away from them rather than towards them?

Emphasis on growth, as in this note, is often criticized as neglecting overriding objectives, such as poverty reduction. No apologies are needed on this count with respect to agricultural growth. My own publications have for four decades spelled out the critical relationship between agricultural growth and poverty reduction in low-income, substantially agricultural countries in which food consumption dominates consumption patterns.

Now, a recent study, published in the *World Bank Economic Review* (Ravallion and Datt 1996), documents this role in irrefutable fashion. Growth in the manufacturing sector does not reduce poverty at all in such countries. Neither does growth in urban areas. Agricultural growth has a major effect in reducing poverty overall, and even has a larger effect in reducing urban poverty than does urban growth. Growth in the large-scale service sector does not reduce poverty either, but growth in the small-scale service sector that is stimulated most importantly by growth in effective demand from rising agricultural incomes does. Even major redistributive efforts, as attempted in India, for example, are puny in their effect compared to rapid agricultural growth. The theory behind these empirical results has long been clearly spelled out.

One final matter on the growth rate. It is the growth rate of agricultural GDP that is most important, not gross output. This is becoming an increasingly important distinction. In developed countries, with very high input levels, attention has shifted to increased input productivity with the result that agricultural GDP tends to grow faster than gross agricultural output—input efficiency is increasing. In contrast, in developing countries, input efficiency has been steadily declining—agricultural GDP grows more slowly than gross agricultural output. This is not only environmentally damaging, but it restrains growth in net farm incomes. Here is a clear case of complementarity of income and environmental concerns. Of course, increasing input efficiency is institutional and management intensive, which explains the problem in developing countries and, of course, the answer to the problem as well.

Implications for National Agricultural Research Systems

At first glance, expanded opportunities would seem to call for research on many more commodities—dispersion of the research effort. But, the reality is the opposite. With global markets, at home and abroad, competitiveness requires the best research. A few decades ago, with more isolated markets, second-class research might be enough to progress; now it will not even allow survival. First-class research means researchers doing research that is of global interest (not necessarily in its specifics, but at least in its approach). Researchers from developing countries must travel to other countries on a regular basis to keep up to date, and similarly, must regularly receive researchers from elsewhere. And they must do so from a position of strength, where they have something to offer as well as to receive.

Now, there is hardly a developing country that the top researchers in the developed countries would want to visit except to collect materials and to use cheap labor. That must change. Researchers in developed countries travel to each other's countries far more than they did a few decades ago. They do so because they must, in order to be up to date in the latest work that is now disbursed across many countries. To make developing countries of interest requires resources that can only be provided with tight priorities that concentrate research on a very small number of commodities. Essentially all developed countries are reducing the range of what they work on and increasing the resources on those priorities. Very few developing countries are making those hard choices; thus, critical mass is lacking for first-rate work.

The national systems of most low-income countries are the victims of donors who thoughtlessly poured in money to allow excessive expansion in the numbers of researchers and in the range of commodities and issues treated, with the consequence that the support for researchers is so thinly spread that little can be accomplished—certainly not at the world-class level that is now required. The response to that thoughtlessness has generally been an emphasis on management and personnel policies and an exhortation for more operating funds in a context where that is not possible.

What to do now? Again, at first glance, drastic retrenchment is in order, cutting personnel drastically, setting a few priorities, and then pouring resources into those priorities. At this juncture, for most developing countries, that choice is not going to be made. The alternative is to pick a few priority areas that will become centers of excellence, and provide management tools, accounting systems, and resources that will allow those very few priority areas to reach world-class status. That means a two-class research system—not an aesthetically pleasing prospect, made worse by the tendency to place politically favored persons in the upper-class system. But it offers some prospect of world-class performance in a few areas, and those few areas could be monitored by objective criteria and a dispassionate set of reviewers. Perhaps domestic lobbies of beneficiaries could be built to nurture and protect those centers of excellence. (It is important to be clear that these are not centers of excellence in basic research. Rather, they are centers of excellence for applied work, most likely commodity oriented, which is where the effective farmer demand will lie, along with the potential to build political support groups.)

The criteria for selecting the priority areas must be clear commercial criteria. One of the many problems with agricultural research in developing countries (and within the CG as well) is a tendency to confuse ends and means. Poverty reduction, environmental enhancement, and empowerment of women are ends of development—and very important ones at that. Agricultural growth, with its base of research to improve technology, is the key means for reaching those ends—indeed, raising rural incomes across a broad basis through accelerated growth gets us most of the way towards those ends (see in particular the striking research by Martin Ravallion at the World Bank on this, commented on above).

By placing the direct achievement (as distinct from broad indirect effects) of those ends up front in criteria for research, the research effort has been diffused, priorities lost, and progress slowed both in agricultural growth and in realizing the ends of that growth. This has been shown clearly in the CG and even more in fragile national systems. To achieve those important ends, the focus must return (as it was in the simple days of Robert Chandler at the beginning of IRRI, "We will double rice yields in Asia") to priorities for growth in production. With an emphasis on applied research, commodities will form the focus of much of that research (again, as was the case in the simpler, early days of the CG system). Of course, *within* those production priorities, one must be sure that women participate (how else can the growth targets be met, with so many women farmers?) and that the effort is sustainable (farmers are the most concerned people in the world about the future of their children and grandchildren). Attention in support systems must also be given to ensuring access by relatively poorer farmers. We now know how to do each of these things.

As suggested above, another criterion in setting research priorities must be complementarity with commercial interests, both in the research and extension tasks. In developed countries, the public and private sectors are increasingly working hand in hand, each finding its comparative advantage. It is the rare developing country indeed that is even thinking along those lines.

The preceding argument gives emphasis to commodity programs. They are a logical focus from an income-raising point of view. Of course, some problems cut across commodities. Attention was drawn in the preceding section to the need for greater attention to increasing input efficiency once input levels reach significant levels, as they have in most of Asia (and, of course, have not in most of Africa). The most obvious needs are for specific attention to increasing efficiency in raising soil fertility and pest management. These are underresearched and most obviously underapplied in developing countries that have intensified their agriculture.

Implications for the CGIAR

The implications for the CGIAR flow naturally from the foregoing discussion.

First, the CG should press low-income countries to reduce their lists of priorities, not press them to expand them, as is often now the case. This includes not only limiting the commodity priorities, but fitting poverty reduction, environmental enhancement, and women's empowerment within the context of basic production, income-generating priorities. The latter will actually enhance progress towards those ends, not slow it, because of the critical role of raising rural incomes to achieving those objectives. The food-crop priorities must be constrained to a short enough list to allow a small number of high-value commodities to also have access to priority resources in order to achieve world-class status.

Second, within the priority areas defined, the CG centers need to work with national systems to define the optimal working relationship. This may well require special funding to allow a strengthening input for commodity programs that can afford to be somewhat weaker (but not absent!) than they would be if the CG centers did not exist, thereby allowing somewhat greater strength in non-CGIAR-supported high-value commodities. These are, of course, decisions for a real world of second-best choices, not the ideal.

Also, given the strength of the CG system in food crops and its commitment to working with even rather weak national systems, the right allocational position is to give highest priority to achieving world-class status in high-value commodities, and to see that the basic food-crop systems are good enough to be able to draw on CG research. In that context, donors need to finance the programs CG centers so that they can work intensively with only moderately strong national systems in basic food crops. Very few centers have marshaled the support to do that. The exceptions (e.g., CIMMYT in Nepal) have given very high returns in the context of very weak national systems.

Third, it is notable how dependent the national systems are on the CGIAR for their agricultural growth in the basic varieties. In the past, that has been seen as deplorable. In the current context of need to establish world-class research in more areas than national systems can afford, it may be that in basic cereals such dependency may make sense for longer than previously thought. But, if that is to be the case, then there needs to be reliability in the CG input, on which at least medium-term planning can be based. And donors need to give more attention to funding the essential, close working relationship between the CG centers and the national systems. Again, the CIMMYT example in Nepal is instructive.

Fourth, research that cuts across commodities, particularly soil fertility and pest management, is beginning to bulk large in Asian countries and will do so in African countries in another decade or two. The international centers can make important contributions in this area.

Is the allocation of funds among and within centers recognizing these needs? It seems doubtful.

Much progress in developed countries is based on relatively traditional approaches to research. However, the promise of breakthroughs from recent basic discoveries in the biological sciences is increasing. Attention is needed as to how low-income countries will access these potentials. Certainly, priority setting will be increasingly important in this context as well.

Epilogue

Time is slipping away. With so many developing countries urban dominated (especially in Africa), with much less donor pressure towards agricultural growth (in contrast to a few decades ago), developing countries are seeing their export-led, nonagricultural growth surge ahead, with agriculture lagging. The undesirable effects of such unbalanced growth are showing in urban concentration, reduced progress in poverty reduction, vast numbers of rural women unempowered, and environmental deterioration in rural and urban areas alike. Growth is accelerating but not the achievement of larger societal objectives. A return to donor emphasis on agricultural growth and its underpinnings of strong technology systems would help.

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The Plight of National Agricultural Research Systems in Low-Income, Food-Deficit Countries

John H. Monyo

Few scientists think of agriculture as the chief, or the model, science. Many, indeed, do not consider it a science at all. Yet, it was the first science—the mother of all sciences. It remains the science which makes life possible. And it may well be that before the century is over, the success or failure of science as a whole will be judged by the success or failure of agriculture.

André and Jean Mayer

Introduction

As early as 1948, the Universal Declaration of Human Rights affirmed that "Everyone has the right to a standard of living adequate for the health and well-being of himself and his family, including food . . . ." Since then the right to food has been characterized as a "fundamental right" and in the words of the former UN Secretary General, Boutros Boutros-Ghali (1996), "It is the primary economic right of the human person." By implication, any nation that cannot assure the majority of its people access to an adequate and nutritious diet at a price they can afford will be doomed to shame and dishonor.

It has been reported that over 800 million people in the world today are without adequate access to food and 200 million children under the age of five are suffering from protein and calorie deficiency (FAO 1996). Most of these people are found in low-income, food-deficit countries that lack the financial resources to buy the necessary additional food on the international market. And yet it is a truism that science and its application to agriculture has advanced so much that currently there is more than enough food globally to feed everybody. The main problem has been, and will remain for many years to come, the accessibility and affordability of the available food stocks to the poor rural and urban consumers in developing countries.

Low-income, food-deficit countries have been defined by FAO as those countries with a per capita income in the range used by the World Bank for lending by the International Development Agency (IDA) and a negative trade balance in cereals, averaged over the previous five years. Currently more than 80 such countries have been designated by FAO as belonging to this group and over half of them are located in Africa. The issue at stake is whether the national agricultural research systems (NARS) in these countries are in a state to benefit from the globalization of science. Unfortunately, many of them do not have the capacity to assess and adapt to their local conditions the knowledge and technologies derived from the basic and strategic research carried out by international agricultural research centers and better-endowed national agricultural research institutions.

Capital and Technology

In any agricultural research institution, getting things done calls for capital and technology. More important, it calls for the practical and idealistic skills by which it is possible to stir, motivate, and release the creative energies of the scientists involved in research. However, due to the poor state of the economy in low-income, food-deficit countries, the required capital or appropriate technology is not available. For some countries, this state of affairs is the manifestation of corrupt government regimes and/or frequent civil strife, despite their rich natural resource base. Even in situations where the capital is available, the political and economic environment might not provide the stability required for appropriate technologies to be generated or adapted and properly assessed before being transferred to farmers. As a consequence, the capacity of research scientists in these countries is rarely fully utilized. It is not uncommon to find NARS in developing countries that could be classified as unproductive and inefficient, but the scientists and research managers running those same systems tend to excel when given an opportunity to work in another NARS or in international and regional agricultural research institutions.

Although there has been a marked improvement in the quality and orientation of public-sector spending for agricultural research and extension in some developing countries over the last three decades (Pardey, Roseboom, and Anderson 1991), the situation appears to have deteriorated in recent years. Many of the NARS have been too dependent on external donor assistance for both infrastructural and operational funds. This type of funding is no longer readily available (a situation referred to as “donor fatigue” in some circles). In some NARS, even salaries for research and administrative staff have become a major burden on the national budget; quite often the staff have to work without a regular salary! This state of affairs has had a serious demotivating and demoralizing influence on many young and potentially capable scientists. They have become an idle asset with few, if any, career prospects in agricultural research in their own countries. In many developing countries, this has led to the so-called brain-drain from emigration.

Globalization of Science

The application of science and technology will continue to play a crucial role in agricultural research and development during the 21st century. It is projected that by 2025, over 80% of the expected global population of 8.5 billion will be living in developing countries. Therefore, improving the capacity of NARS to ensure increased and sustainable production and productivity of agricultural lands to support the additional 2.8 billion people must receive the highest priority—particularly in those countries presently classified as low income and food deficit. This matter has become particularly important in the light of the Rome Declaration on World Food Security and Programme of Action approved by the World Food Summit held at FAO in November 1996. The Programme of Action has the daunting task of reducing (from the current 800 million to 400 million) the number of people who are undernourished and unable to enjoy healthy and active lives by the year 2015. While the provision of food security for 400 million poor people would in itself be a sobering goal, it must also be realized that the world population is projected to increase by about 90 million people every year.

The Challenge Ahead

The challenge facing governments and NARS is to provide food security in 2015 not only for 400 million of the 800 million people presently undernourished, but for an extra two billion! Will the present effort be enough?

Based on recent trends, the current effort might reduce the number of chronically malnourished people to 600 million in 2015. To attain the World Food Summit target of 400 million will obviously require a much greater effort, for which a multitude of mutually interrelated actions will become necessary. Many of these actions will have to be directed to the development of appropriate policies and socioeconomic frameworks. Nevertheless, effective agricultural research—at both the national and international level—will play a vital role to meet the essential food needs of the remaining 200 million chronically undernourished people.

Several studies conducted in developed and developing countries by various institutions over a number of years have demonstrated that investment in agricultural research has high rates of return (Ruttan 1982). Since then a large number of studies undertaken by the International Food Policy Research Institute (IFPRI) in Africa and Asia (Haggblade and Hazel 1989; Haggblade, Hazell, and Braun 1989; Pinstrup-Andersen, Lundberg, and Garret 1995; Delgado et al 1997) have reconfirmed the earlier findings from the perspective of public-sector investment in national as well as international agricultural research. The latter findings have shown that for every dollar of increase in agricultural incomes, the overall national economy increases its income by two and one-half dollars. In other words, for each additional dollar of income generated in agriculture, an additional one and one-half dollars are generated from outside agriculture. The data also showed a positive correlation between investment in international agricultural research and developing-country imports. Every dollar invested in international agricultural research increases the ability of developing countries to import goods and services from developed countries by more than four dollars! This investment generates improved market opportunities for the donors as well as for the beneficiaries of international agricultural research in developing countries. Therefore well-organized and properly funded national and international agricultural research is an essential precursor for social and economic development.

Presently the public sector invests 1.5 billion dollars annually in international and national agricultural research and extension systems in developing countries. If this level of investment were withdrawn, it is reckoned that the world production of cereal grains in the year 2020 would be about six percent less than currently predicted and 10 percent less in developing countries. But, if this level of investment were increased by 50 percent, global production of cereal grains would *increase* by six percent. Such an increase would be equivalent to 95 million additional tons of grain produced in developing countries by 2020 and would be enough to provide the essential food needs of about 350 million more people, a figure which is very close to the target set by the World Food Summit for 2015.

Towards a Research Strategy for Low-Income Countries

To start with, the problems of an institutional and resource nature outlined by Nickel (1996) regarding the current situation in NARS must be overcome or greatly reduced in order to provide a conducive and an enabling policy environment for effective research. Equally important will be the need for improvements in the organization and management of national agricultural research. Enhanced training and capacity building could play an important role in improving the efficiency and productivity of NARS with respect to research planning, execution, and management. However, political stability at national and regional levels as well as the availability of adequate funds for research will be necessary if the NARS and their partners in the global agricultural research system are to make a positive contribution to economic development in the affected countries between now and the year 2015.

Given that many low-income countries do not have (and some may never be able to afford) the financial and human resources needed to ensure the sustainability of their NARS, they will not be in a position to address the most important production constraints for their major commodities and farming systems in an effective manner. The best strategy for priority setting and organization of agricultural research in these countries, including the procurement of the required investment, remains an unresolved question. Traditionally, priority setting and the organization of research in the agricultural sector at both the national and international level begin with a discussion of the physical characteristics followed by the biological dimensions, and in some situations, a micro-social dimension—such as the major farming systems. Quite often, this approach does not include an explicit consideration of the broader (macro) economic and social dimensions such as population, income level and distribution, social and economic organization and public policy (McCalla 1991). And yet these factors play a crucial role with respect to both the final impact of the research effort and a better understanding of alternative sources of the supply of research. These macro-social dimensions are greatly influenced by national boundaries.

It seems prudent therefore, and indeed necessary, to take both ecological characterization and socioeconomic data into account when planning national research programs. The research and implementation chain has many modifiers: first, there is the agroecosystem, which determines the potential for improving the productivity of research (the productivity potential of an agroecosystem can itself be significantly modified by irrigation); second, there is the probability of the research results being adapted to local conditions and extended to farmers; third, there is the probability of wide-scale adoption of the technologies by farmers; and finally, there is the likelihood of impact on production that promotes food security through increases in supplies and reduced prices for consumers. While conventional agricultural research planning in national as well as international institutions can contribute easily to improvements in productivity and even to local adaptation of research results, an approach that combines agroecological considerations as well as the macro-socioeconomic dimension would greatly help to resolve those issues related to technology adoption and therefore increase the probability of production impact. Here probably lies the most feasible option available to low-income, food-deficit countries to achieve reasonable progress and make an effective contribution towards the achievement of sustainable food security through research. This approach has been termed "ecoregional" by the Technical Advisory Committee (TAC) to the CGIAR (TAC 1991). The notion of an *ecoregion* involves agroecologies regionally defined—in which regions are defined as being groups of countries—such as the warm subhumid tropics of Africa.

The ecoregional approach makes it possible for NARS, IARCs, and regional agricultural research institutions to take into account ecological characteristics and socioeconomic data in their priority setting, research planning, and problem analysis. Research planned and organized along ecoregional lines offers opportunities to minimize unnecessary duplication and to ensure better synergies between NARS, collaborating IARCs, and regional agricultural research institutions. This approach also makes it possible to organize and strengthen research partnerships in the manner suggested by Nickel (1996) and Javier (1996).

Although the ecoregional approach does not claim to provide a panacea for effective agricultural research in low-income, food-deficit countries, it facilitates the linking of research programs on productivity improvement and natural resource management. It also provides a mechanism to formalize and strengthen close collaboration among NARS and extension services, IARCs, international research and development organizations, and relevant stakeholders. It allows the implementation of research and development activities in a holistic manner. Finally, it promotes the participation of farmers in technology development and ensures a more conducive environment for agricultural research and development.

The Participatory and Gender Dimensions

A considerable amount of good research has been done in developing countries. In the case of the low-income, food-deficit countries, the research was done largely through external technical assistance and financial support. However, this effort has not achieved the expected impact on agricultural and economic development in the majority of these countries, meaning that much time, effort, and scarce financial and human resources have been wasted by these countries as well as by the supporting donor agencies. The poor show this implies has also tended to give bad press to national agricultural research and has encouraged a hands-off research attitude among some influential local politicians. This "failure" can be explained partly by the lack of a participatory approach in the planning and execution of national research programs. Participation of farmers and extension agents in the analysis of socioeconomic and production constraints and in the assessment and adaptation of new technologies has been shown to increase the rate of adoption of improved technologies by farmers. Their active involvement and contribution to the development and testing of technological packages generate a demand pull.

Another major factor that is responsible for the low rate of adoption of improved technologies is the lack of a gender perspective in the planning and execution of national research activities. In most low-income, food-deficit countries, women constitute more than 60 percent of the labor force in the farm/household systems. Recent studies by a number of IARCs indicate that there is a marked increase in the feminization of agriculture in all developing regions as more and more men leave the rural areas in search of more remunerative employment opportunities in towns and cities.

The participation of women in research planning and technology assessment has many positive effects on the cost-effectiveness and productivity of the research effort. Women have a better understanding of the postharvest dimension of food security in agricultural research because they are the primary food processors and feeders of their families. Furthermore, results emanating from policy research have shown that more women than men use their additional income for the nutrition of their children. And last, women are reported to have a larger stake in improved natural resource management; therefore, their knowledge and constraints can assist in devising technologies that improve the sustainability of these resources. A panel discussion on "Meeting the Technology Needs of Poor Rural Women" organized during the 1996 CGIAR International Centers' Week in Washington, DC, concluded that addressing the technology and policy needs of poor rural women in agricultural research contributes directly to poverty alleviation, equity, and improved sustainability of agricultural production. In conclusion, the knowledge and experience of women and particularly those living in rural areas in developing countries should be recognized as being essential in any effort geared towards the attainment of sustainable food security.

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A Global Agricultural Research System for the 21st Century

John L. Nickel

Agricultural research has a proud history. The technology it has produced has been the fuel with which agriculture has served as the engine of development and made it possible for a smaller number of farmers to produce food and fiber for a larger number of people at lower cost. Numerous economic studies have demonstrated that agricultural research provides huge returns on investment. Now, however, just as the world desperately needs new technology to feed and clothe a growing population in the face of a declining natural resource base and a changing climate, agricultural research is in a state of crisis. Throughout the world, in developed as well as developing countries, national and international budgets for agricultural research are declining in real terms. The national and international institutions that have evolved for agricultural research are inadequate to meet the challenges of the 21st century.

Introduction

This paper describes the current status of national and international agricultural research systems, analyzes the principal problems that limit the effectiveness of these institutions, and presents a vision for the future of agricultural research. It concludes with a discussion of the types of issues that need to be addressed in order to accomplish that vision.

What follows pertains generally to agricultural research in all countries, irrespective of the state of economic development. Principal emphasis, however, is on agricultural research as it pertains to poorer, less-developed countries and regions, for it is here that populations are increasing most rapidly and current levels of nutrition are most in need of improvement. All agricultural research systems need increased support and improvements in their management, but the more affluent societies can better afford the luxury of inefficiencies inherent in the organizational structure of public-sector institutions. Furthermore, they also have a more developed private sector with strong involvement in agricultural research. All countries would, however, benefit from some of the centralized, international agricultural research services proposed here.

National agricultural research systems (NARS) are the key actors in this drama. These are the only institutions that can transform scientific knowledge and technology from various sources into technological components with which the producers in their countries can develop more productive and sustainable farming systems. And they are the ones who can best link with local governmental and nongovernmental agencies for dissemination of this technology. It is likely, therefore, that there will be a continued need for public-sector NARS well into the 21st century. As the private sector develops to play a greater role in technology generation, and nongovernmental organizations (NGOs), including producer associations, increase their participation in technology validation and transfer, the NARS will need to evolve accordingly. And if they wish to attract the levels of financial and political support they need, they must become more effective and efficient.

The Current Situation in National Agricultural Research Systems

Description

NARS vary greatly in size, organizational structure, effectiveness, and level of support, and each is distinctive, depending on its institutional, cultural, and political environment. Nevertheless, it is possible to identify a number of generic problems that can be found in the vast majority. The following description of these problems is necessarily a broad generalization. Although the whole set probably does not apply fully to any individual institution—and some NARS may be free of many of them—the list of generic problems is sufficiently applicable to serve as a guide to the types of issues that must be addressed in transforming the NARS to more effectively play their key role in the future.

Most of the NARS exhibit some, and some exhibit many, of the following weaknesses.

Problems of an institutional nature

Poor interinstitutional collaboration, the most serious examples of which are

- mutual antagonism and lack of cooperation between institutions charged with agricultural research and university faculties of agriculture and of science;
- ineffective linkages between animal and crop research;
- insufficient use of socioeconomic disciplines;
- relegation of “farming-systems” research to separate, isolated units, rather than promotion of the concept that most scientists should conduct on-farm research with a farming-systems perspective;
- ineffective linkages between research and extension activities;
- ineffective linkages between public-sector and private-sector research;

- insufficient involvement of farmers in setting research agendas and evaluating results;
- dispersion of agricultural research through a large number of ministries and institutions;
- excessive intra-institutional fractionation, with scientists and equipment dispersed to too many small stations, resulting in a lack of critical mass for efficient use of facilities and appropriate coaching, mentoring, and collaboration;
- civil-service-type regulations for human resource management (i.e., lack of functional flexibility).

Resource problems

- severe underfunding;
- resource allocation by commodity and research area, which does not reflect national priorities and farmers' needs;
- inappropriate resource mix, with too high a percentage of the budget dedicated to personnel and not enough for operations;
- overly centralized procedures for resource allocation;
- excessive dependence on externally funded projects for purchase of equipment and vehicles;
- inefficient use of expensive, specialized equipment and facilities because of ineffective linkages and fractionation;
- limited resources spread too thinly over a large number of commodities/research areas, without adequate prioritization;
- budgets allocated and reviewed by station rather than by area of research;
- budgets largely a compilation of requests rather than a tool for an effective resource allocation process.

Organizational and management weaknesses

- hierarchical management structure and attitudes (versus "flat" structures and collegiate management style more conducive to scientific innovation);
- adherence to cumbersome bureaucratic procedures for purchasing;
- insufficient delegation of authority;
- lack of management information;
- inadequate procedures for budget preparation and review;
- inadequate planning, monitoring, and evaluation of research;
- weaknesses in individual performance evaluation;
- promotion based strictly on seniority rather than merit;
- heads of institutions and units not selected on basis of management performance;
- inadequate management and leadership training;
- lack of motivation of staff.

In addition to these institutional problems, there is also a widely held view that the quality of scientific personnel has fallen in many countries. It is often felt that this is because salary scales are not competitive, resulting in the loss of the best scientists to the private sector or international organizations. This is no doubt an important factor, but a more important, underlying factor may be the deterioration in the quality of teaching in local universities, accompanied by a decrease in the availability of scholarships for study abroad. Many of the universities are seriously underfunded but, at the same time, are required to take on growing numbers of students. The resulting increased teaching load and lack of adequate facilities and equipment have had an adverse effect on the amount and quality of research in the universities. The existence of high quality and relevant research is essential for quality agricultural education, especially at postgraduate levels. The lack of interinstitutional collaboration, mentioned above, not only has an effect on the relevance of university research, but more important, it implies that those agricultural scientists with the highest academic qualifications who are located in the universities do not contribute as much as they might to the solution of the key agricultural production constraints

Analysis

The principal problems of most NARS cannot be attributed to the quality of their human resources. Indeed, one can point to many examples of scientists from these same countries who are among the most skilled and productive researchers in the international agricultural research centers. What makes them so productive under these conditions, when many were much less effective at home, is chiefly the effect of having placed them in a more productive institutional environment. This underlines the critical importance of improving the organizational structure and research management in the NARS.

National leaders have recognized that these problems exist, and various attempts have been made to correct them, often through externally financed projects. The NARS, and these projects, have benefited greatly by the work of ISNAR. ISNAR has sent teams to the various countries to diagnose the current situation and recommend improvements in organizational structure and management practices. It has also developed research management tools and has disseminated them through publications and training programs. As a result, there has been considerable improvement in the effectiveness and efficiency in some NARS. However, many of the problems persist.

The principal reason that the efforts of NARS leaders, ISNAR, and various donor agencies have not succeeded in overcoming these weaknesses is because the NARS continue to operate in a cultural and political environment that is not conducive to the needed changes. To overcome this, various models of semi-autonomous institutions have been created. The rationale for such institutional development has been that more autonomous bodies would be free of political influence in the appointment of staff and that they would have more flexibility in establishing their own personnel and administrative policies. This would make possible more attractive salary scales and promotion based on merit, as well as facilitating financial management and procurement. Yet, rarely have these new institutions really been given the flexibilities that were intended, nor have they used those they have.

No institution that is dependent chiefly on public funds can be fully autonomous. If it receives public funds, it must use them in a manner that is responsive to the needs of the greater society and it must act within the framework of national policies. That is why these institutions are referred to as "semi-autonomous," rather than "autonomous." That, however, is not the crux of the problem. Often, the prescribed institutional changes have not been made, have not been allowed to take effect, or have been halfheartedly implemented only to the extent that will not hold back the next donor payment. When the reasons are explored, it becomes evident that one or more of the following factors are involved:

- the Minister of Agriculture (or the equivalent) was not willing to cede control of the institution;
- the new personnel policies, if developed, are not much different from those of the line departments;
- administrative procedures and financial controls are still burdensome.

Improving salary scales to attract and retain the most competent scientific staff does not improve the quality or productivity of research if selection procedures and/or an effective evaluation/reward system are not in place. What procedures there are, are often defective or not effectively administered, because, if the truth be told, staff are not comfortable with a true merit system. The typical civil-service rules and procedures, in which selection, annual salary increases, and promotions are based on seniority rather than performance, were put in place to avoid favoritism. While this is important, they have become a "security blanket," which most people are reluctant to give up. This is compounded by the existence, in many countries, of laws that make it practically impossible to sanction or dismiss unproductive employees, even if they are no longer employees of line government departments. The result is that good performance is not rewarded and poor performance is rarely punished. This is probably the most damaging of all of the weaknesses in the NARS. Unless it is courageously remedied, these institutions are condemned to mediocrity, at best.

The institutions' top management also feel more comfortable with bureaucratic government procedures than more flexible systems of financial management and procurement, as these protect them from being accused of mismanagement. The most innovative and dynamic leaders, who find ways to get things done in spite of the government bureaucracy, are particularly vulnerable to such attacks. Reasonable safeguards must be in place to avoid abuse, but more agile systems are essential. This is particularly important in agricultural research, in which long delays in release of funds or in procurement of supplies and equipment often mean that these resources become available too late in the agricultural season.

The problems listed above are the principal reasons why institutional changes meant to improve national agricultural research systems too often are only cosmetic and haven't achieved the desired improvements in research quality and productivity. Bold transformations of laws, regulations, and attitudes will be required to enable them to effectively carry out their vital missions, and to merit the increased financial and political support they so badly need.

International Agricultural Research

Description

The international agricultural research centers (IARCs) coordinated by the Consultative Group on International Agricultural Research (CGIAR) make up the principal international component of the global agricultural research system. As currently constituted, they focus on research and training to support sustainable agricultural production in developing countries, and work in close partnership with the NARS. The rationale for such an international dimension of agricultural research can be summarized as follows:

- the ability to form international, multidisciplinary teams of highly qualified scientists in "centers of excellence" to concentrate on sharply focused efforts on a limited set of high-priority research areas;
- an economy of scale in utilizing specialized scientists and facilities to generate knowledge and technology as "international public goods" that can be utilized and adapted by the NARS for use in their respective areas of responsibility;
- status as autonomous, international institutions, which makes it possible to create an institutional environment free of many of the problems inherent in national institutions, as described above.

If something like the CGIAR did not exist, it would need to be invented. The good news is that it does exist; the bad news is that it needs to be invented again. It must be reinvented for two reasons: (1) it has lost its way and (2) its current structure and portfolio are inappropriate for current and future circumstances. Revitalization of the international agricultural research system cannot be achieved with a few adjustments: a major transformation is needed.

The CGIAR system is arguably the most important institutional development in the history of agricultural research, and even with its many current faults, it is probably the best investment that can be made of foreign aid funds. Why then are donors losing interest, and why is there less respect for the CG system and its constituent IARCs as being productive and relevant? It has become too large, too bureaucratic, and too politicized. The excitement and youthful agility it possessed when it began in 1971 have vanished; it has become a 25-year-old that is arthritic and verging on dull senility. This statement is, of course, an oversimplification of what happened along the way as an international agricultural research system evolved from an exciting set of highly relevant and productive research and training activities in four agile and flexible centers to a large international bureaucracy struggling to manage and support 16 diverse international centers. Many things have been done correctly along the way, and the contributions of the CG system to human welfare over the years are immense, praiseworthy, and well documented. But a number of things have also gone very wrong.

The most damaging developments have been politicization and loss of focus. These problems have been compounded by declining financial support on the part of the traditional donors. At the same time that the centers have been expected to broaden the scope of their work, they have had to do so with less funds. In spite of the noble efforts of the CGIAR chair to mobilize more funds, centers have had to drastically reduce programs and staff. The reasons for declining foreign aid budgets and apathy about the world food situation are well understood. Nevertheless, world food stocks are at low levels, and only a few droughts or floods here and there could well bring on new food shortages of catastrophic proportions. Then public and donor support might well be aroused anew, but it would be a shameful tragedy if the ability of the international centers to prevent, or respond to, such a crisis had by that time been dismantled. To this it must be added that the task of making the earlier gains in food production more sustainable is far from completed.

Analysis

To say that the CG system has lost its way is not to say that the system should not have changed over the years, or that it should not change dramatically in the future. Change was inevitable and desirable. Indeed, when the first centers were conceived, it was generally assumed that they would work themselves out of a job, after which they would cease to exist as international institutions. These views have been modified as it has become evident that the task of feeding a rapidly growing population is far from over, and as it has become apparent that sustainable agricultural development is a much more complex task than simple varietal improvement. It is now clear that some form of centralized, specialized research in support of the work of the NARS will be needed well into the 21st century. But the nature of these efforts must necessarily change as the nature of the priority problems change, and as new scientific discoveries open new opportunities for major technological advances. Therefore, this paper is not a call to preserve the system as it was, or to promote an attempt to go back to the "good old days."

The centers have changed. They have evolved to reflect the results of research progress—the growing competence of NARS to take over much of what was done at the international level earlier—and to assume additional responsibilities related to the issues of sustainability and environmental degradation. What was not inevitable or desirable is the way in which some aspects of the CG system have changed, and the concurrent loss of donor interest in supporting the centers and their vital work. A transformed system must overcome the chief current weaknesses, and donor support for the revitalized system must be mobilized.

It would not be helpful to present here one person's analysis of why the CGIAR has lost its way. More constructive, perhaps, would be to try to identify those elements of the system, and of the individual centers, that most contributed to the success of the approach represented by the CGIAR and international-center model. These are described with the hope that they can serve as a guide to elements that should be preserved, or reincorporated, in whatever new models are developed for the future.

The most important positive elements of the early CGIAR were

- Informality. The lack of legal status, a system of agreement by consensus, and absence of a formal written record of individual interventions contributed to an atmosphere of collegiality.
- Sharp focus. The initial focus on improving human welfare by increasing basic food production in developing countries provided a clear set of goals whose impact could be measured and which donors could support.
- Commitment. Those who participated shared a strong devotion to the common goals of increased food production, improved nutrition, and the alleviation of poverty.
- Professionalism. Representatives of the various donor and center delegations, the cosponsors, and the members of TAC and of the TAC and CGIAR secretariats were in most part eminent agricultural scientists with experience in agricultural research and development.
- Diversity. The donors included national governments, multilateral organizations, regional banks, and private foundations. These, plus regional NARS representatives, provided a diversity of views that helped lessen the political influence of individual countries and provided valuable inputs to the discussions.

The institutional mechanisms and management style of the "international-center model" that most contributed to the success of the early centers were

- Excellence. The concept of "international centers of excellence" enabled the centers to select an elite cadre to accomplish their objectives. It made it possible for them to provide facilities and salaries that would attract and retain the best international scientists and to recruit the most qualified persons for each specific task, without reference to national origin, creed, or gender.
- International character. Their status as autonomous, international institutions freed the centers' management to develop personnel policies that rewarded merit and to dismiss nonproductive or redundant internationally recruited staff. This served to motivate staff to high productivity and made possible flexibility in modifying staff composition to meet changing circumstances.
- Governance. Self-perpetuating boards, made up chiefly of persons serving in a personal capacity, enabled the selection of eminent persons from various disciplines and nationalities to guide the policies of the centers and to select top management relatively free of external influences.
- International mobility. The provision of adequate travel budgets and an international mandate made it possible, and necessary, for international staff to travel extensively in their zones of influence, facilitating a better awareness of the needs of NARS partners and farmers and catalyzing valuable exchanges of information and experience.

- **Mission orientation and focus.** A clear mandate on specific commodities and research areas enabled the centers to develop multidisciplinary teams with the critical mass and sharp focus needed to resolve the highest priority production constraints in their mandated research areas.
- **Training.** From the start, the centers devoted major efforts to group and in-service training of scientists from the NARS of their target areas. This helped to develop strong partnerships and contributed substantially to the strengthening of the NARS.

Vision for the Future: General Concepts

A new, global agricultural research system must evolve. Just as the nature of national, political boundaries are becoming more blurred with the globalization of the economy and dramatic developments in the flow of information, the nature and roles of agricultural research institutions need be modified to reflect such changes. Progress in scientific knowledge and information exchange should be seen as opportunities, not threats. Scientific progress in molecular biology and genetic engineering open new frontiers for increased agricultural production that is more sustainable, makes more efficient use of nonrenewable resources, and causes less environmental pollution. The information revolution, exemplified by the Internet, CD-ROMs, and portable, miniaturized communication devices, will provide easier, instant access to information on scientific developments to scientists in NARS throughout the world. As a result, current distinctions between developing and developed countries, and between national and international agricultural research, will become progressively obscure.

One possible scenario for a more globalized agricultural research system would be a three-tiered structure of regional, national, and international research institutions. Each would have a distinct role, but their relationships would be interactive and mutually dependent. New regional institutions would assume responsibility for much of the strategic and applied research now being conducted in national and international institutions. What remained of the current NARS would concentrate chiefly on location-specific applied and adaptive research, with a strong emphasis on participative on-farm diagnostic and technology validation activities. A set of international centers, reduced in size and number from the current IARCs, would focus on more basic, upstream research to provide the knowledge and genetic materials required by the regional institutions.

Regional Agricultural Research Institutions

Rationale

Many small and medium-sized countries do not have the financial or human resources to build the critical mass of scientists and facilities needed to resolve the most important production constraints for each commodity and agroecosystem in their nation. Furthermore, their limited resources are not efficiently used as their work is often duplicated in neighboring counties. This is not to say that there has not been any regional cooperation. The IARCs have promoted the development of a large number of collaborative research networks along specific commodity and other lines. Leadership of these networks has progressively been assumed by scientists from the NARS in the respective regions.

A more recent development, which goes well beyond such collaborative research networks, is the emergence of a range of regional groupings in agricultural research, especially in Africa and Latin America. In Africa, four important regional associations are being developed: SACAR (Southern Africa), ASARECA (Eastern and Central Africa), CORAF (Sahelian zone) and INSAH (Western Africa). In Latin America, there are PROCISUR (Southern South America), PROCIANDINO (Andean countries of South America), PROCITROPICOS (tropical belt of South America), and CARDI (Caribbean islands).

The networks and regional organizations described above are principally coordinating mechanisms, not institutions for hands-on research. They hold the potential for promoting research collaboration and a division of labor, but they also tend to remove some of the most capable scientists from active research in their respective NARS. The negative trade-off to improved efficiency is the inherent danger that they might become just another bureaucratic layer in the process of research program planning and approval. While some of these regional groupings may well serve as the basis for the development of the regional institutions suggested here, they are not a substitute for such a structure. What is proposed here is new regional research institutions that would have a staff of active research scientists working in research laboratories and fields.

It is envisaged that most of the current NARS would consolidate their agricultural research into regional agricultural research institutions (RAIs) . The very large NARS (e.g., China, India, Indonesia, Brazil, Russia, USA) are, in effect, regional institutions and would continue to serve as such in this scenario.

Organizational structure and governance

Individual countries in a given physical or ecological region would agree to merge appropriate components of their current agricultural research systems into the new regional institutions. This would be done by international agreements between the member countries. Preparatory activities for this transformation could be sponsored by international agencies, such as the World Bank, ISNAR, and FAO. These agreements should, among other things, specify the nature of the governance of the RAIs. As these would be intergovernmental institutions, the members of the governing bodies would be chiefly representatives appointed by the member countries.

Facilities

Establishing the RAIs would necessitate little, or no, construction of new research facilities. Existing centralized agricultural research institutions in each NARS would generally become part of the new regional institutions. Their facilities and equipment would, in many cases, need to be rehabilitated and upgraded. Most current regional NARS stations would probably remain part of the residual national institutions, but some might be needed for the regional bodies to ensure adequate coverage of key agroecological regions. It is envisaged that some of the current IARCs would be converted to regional institutions, and parts of others could well be handed over to, or used by, the RAIs.

Staffing

RAI staff would be carefully selected from the scientific human resource base of the member countries. Scientists from other countries may also need to be contracted or seconded to fill key scientific gaps. The staff would be employed by the RAIs, and thus would no longer come under the personnel policies of their home countries. In order for the RAIs to attract and retain the best scientists, salaries and benefits for these staff should be significantly better than those prevailing in their home countries. In return for this, these employees would agree to the personnel policies of the RAIs and thus would forego protection under the laws and regulations of their home countries. This would help alleviate many of the weaknesses of the NARS discussed above.

Funding

The RAIs would be financed by legally binding contributions from the member countries, as specified in the international agreements, based on budgets approved by the respective governing bodies. This could be facilitated by loans, designed specifically for this purpose, to the individual countries by international and regional financial institutions. Additionally, these institutions should be eligible for grants from the international agricultural research fund, described under the section on international agricultural research, below.

Consideration should be given to establishing the RAIs as regional, postgraduate universities. Graduate students from member countries would conduct their thesis research under the guidance of RAI scientists and thus contribute to the solution of key production constraints in the region. Development of the RAIs as regional centers of excellence that provide postgraduate education would help to alleviate the declining quality of agricultural education mentioned above.

National Agricultural Research Institutions

The residual components of the NARS would continue to play a key role. The regional stations of the NARS are in closest contact with local farmers and technology-transfer agencies. They would have the important responsibility of diagnosing the constraints of local farming systems; conducting participative, on-farm experiments and validation trials; and forming linkages with local governmental and nongovernmental extension activities. They would also conduct location-specific research to adapt the technologies emanating from the regional institutions to the ecological and socioeconomic conditions in their areas, as well as providing important feedback to the process of technology generation. The understanding of farmers' problems by the NARS would form an important input to the research planning and prioritization functions of the RAIs; thus, their leaders should be included in the appropriate planning and evaluation committees and workshops of these institutions.

International Agricultural Research

Rationale

An important role is still envisaged for the IARCs. But their number, size, and the scope of their mandates would be reduced. And the way in which their work and support are coordinated would be significantly modified. Their principal function would be to develop the scientific knowledge, techniques, and materials used by the RAIs and the larger NARS. They would focus their work on the types of research that require concentration of specialized scientific human resources, equipment, and facilities around specific topics that can be done more effectively and efficiently in a centralized manner. Their most important activities would probably revolve around biodiversity, genetic characterization and enhancement, and sustainable management of natural resources.

The international character of the interrelated activities in preservation of biodiversity and genetic characterization and enhancement is clear. These activities involve highly specialized molecular biology, such as mapping the genomes of the most important agricultural species, and manipulation and preservation of these genes. The international nature of work related to sustainability and natural resources is less clear. Obviously, genetic research and molecular biology can make an important contribution to these issues, as genes are identified and manipulated for characteristics such as drought tolerance and resistance to pests and diseases. Related activities would also include the identification, preservation, and distribution of plants species and genotypes that can be used to develop sustainable farming systems. Some basic and strategic research in areas such as soil and water management are probably also of the nature that can best be done in centralized, specialized laboratories. Much of the work in developing sustainable cropping and animal production systems, is, however, sufficiently location specific that it could probably best be done by regional and national institutions. There are no doubt also some nonbiological/physical issues, such as food policies and institutional development, in which specialized institutions could provide international public goods and services that would continue to be of value to regional and national components.

Research agenda

The research agenda of the international agricultural research system must change to meet new needs and opportunities. Not only will the nature of the research move upstream, as discussed above, but the portfolio of commodities covered must reflect the changing priorities of developing countries. This implies moving away from the principal focus on basic food crops and the needs of small farmers towards greater emphasis on cash crops and technologies that can supply products at the lowest cost. The initial emphasis on basic food crops was appropriate to help overcome the projected food/population crisis. These crops are still important and should not be neglected. However, the principal cause of undernutrition and malnutrition is poverty, and poverty alleviation can best be achieved by lowering production costs and increasing farmers' income.

The focus on small-scale farmers, largely induced by donor pressures, is shifting to greater emphasis on technology that will make it possible for farms of any size to produce food more cheaply. It is now evident to the NARS, donors, and centers that merely increasing the yields of low-value subsistence crops will not raise the incomes of small-farmer families sufficiently to lift them out of poverty. Many countries have embarked on programs that encourage these farmers to incorporate higher-value crops and animals into their farming systems. Also, new international trade agreements and the restructuring of developing economies have shifted goals from food self-reliance to food security. The latter pays greater attention to export commodities and the principles of comparative advantage. These policies aim at increasing foreign exchange earnings, whereby food that can be grown at lower cost elsewhere can be imported. These trends are likely to accelerate in an increasingly globalized market economy. Consequently, the scope of commodities served by the international agricultural research system must be broadened in the future.

Organizational structure and governance

Even as the research agenda of the IARCs is expanded to include key export and non-food commodities, the scope of work on the species they cover, and other research areas, should diminish. Regional and national agricultural research institutions will assume much of what the IARCs have been doing in crop improvement and farming systems research. Much of the research related to sustainability and natural resources would also be handed over to national and regional agencies. Therefore, the number, size, and mandates of IARCs can probably be reduced. Some should become RAIs; others could hand over some of their facilities to RAIs. The future work of the IARCs that is of an international nature would not all be done by IARC scientists or fully financed by the IARCs. These centers should have core teams of highly qualified scientists in their respective activities and make available their facilities for scientists from various universities and research institutions to come and work alongside IARC staff on closely related research projects. In this way, the IARCs would not need to support a large staff, but the excellent facilities that have been developed could be used to serve the common international good. Core staff would promote the development and funding of research projects in their mandated areas, which would be conducted collaboratively, using the gene pools and facilities that are in place.

The residual, individual IARCs should continue to operate as autonomous, international entities, governed by self-perpetuating boards made up chiefly of eminent persons serving in a personal capacity and selected on the basis of their qualifications rather than national origins. How the work of these individual institutions would be coordinated and monitored is, however, a key issue that needs to be addressed. Very likely, the CGIAR, as we now know it, would cease to exist. What should replace it to ensure that the IARCs are well governed and managed, and that they continue to do work of the highest quality and relevance, is an important problem. This conundrum is directly related to, and may be resolved by, the issue of funding, discussed below.

Funding

Agricultural research at the national, regional, and international levels is underfunded. Furthermore, agricultural research, to be effective, requires stability in funding. For a while, adequate and stable funding was assured through CGIAR mechanisms. But the era of assured funding of TAC-approved budgets has ceased to exist and is unlikely to return. Centers are now forced to become much more aggressive and innovative in supporting their activities through sets of individual projects. While this has introduced greater discontinuity and demands much of the time of scientists and management, it has had the positive effect of creating greater accountability. As a greater proportion of funds come from countries that benefit from the research, funding will move towards the goal of being beneficiary-financed and demand-driven. Yet, it would be highly desirable to have a large, stable source of international funding to support the core activities of the IARCs and, if possible, to provide funding for regional and national efforts as well.

It is suggested that an international fund for agricultural research (hereafter referred to as the "fund") be established and that aggressive efforts be made to secure contributions to this fund. Ideally, the corpus of the fund would be sufficiently large so that only the income from the fund would be used for grants to agricultural research institutions. As the likelihood of creating such a large corpus is small, a mechanism to ensure continued replenishment of the fund would be required. A discussion of several possibilities for such mechanisms to build and sustain the fund follows. These alternatives are not necessarily mutually exclusive.

- Burden sharing. This arrangement would retain the CGIAR structure (or something similar) but would replace the current system of voluntary contributions with one in which the members would agree to *mandatory* contributions of a fixed percentage of the approved budgets for the system. This would be similar to the burden-sharing arrangements for various UN agencies and would carry with it all the problems associated with intergovernmental bodies. A greater degree of politicization than the CGIAR has experienced could be expected.
- Taxes. The food and feed industries should be expected to pay for the research on which these enterprises depend. A small tax on the products themselves, or on the international commerce in agro-industrial products, could provide the needed funds. An interesting variation on this theme might be a tax on pet foods. As some pet foods compete directly with humans for food grains and some people are so hungry they might gladly eat food that is being fed to pets in richer societies, this would relate the funding mechanism directly to the problems of food and nutrition. An appealing feature of an international agreement by which nations would pledge to contribute a fixed percentage of what is spent in their countries on pet food is that it would be equitable. As there is probably a close correlation between level of affluence and national expenditures on pet food, less-developed nations could pride themselves in giving the same percentage as richer countries, while contributing much less in absolute terms. A very small percentage would provide enough money to adequately fund national, regional, and international research. One can easily imagine a negative public reaction to another tax, however, so this idea would be unlikely to fly without a clever publicity campaign, with slogans such as "every time you feed your pet, you are helping provide food for hungry people." A simple tax on agro-industrial products is, however, probably more feasible.
- Voluntary contributions. Both of the first two suggestions given above imply international agreements. Getting a large number of parliaments or congresses to ratify such treaties would be a gargantuan task. Thus, the most feasible path seems to be one of voluntary contributions by international agencies, individual countries, NGOs, and the private sector. Support from the private-sector corporations engaged in international trade in agricultural products and agricultural equipment and machinery should be aggressively sought. These corporations, after all, benefit greatly from agricultural research and should be willing to contribute to its cost. As the international centers would be providing products and services that can be utilized by NARS in developed as well as developing countries, national governments should be convinced that the fund is in their national interest. Since improved agricultural production is basic to the success of many development loans, the international and regional financial institutions should continue to provide a major portion of the fund's resources.

The fund should be managed by a governing body that would approve contributions and monitor the effectiveness of the work it supports. This would replace the current CGIAR. Although those who manage the fund would be concerned that the grants it makes are for relevant and effective research, they should not attempt to control the institutions to which they make these grants. Accountability should, instead, be assured by making the grants for fixed time periods, renewable on demonstration of good performance. Although the major contributors to the fund should have confidence that their views are adequately represented, every effort should be made to keep the governing body small enough to be effective and to have its members act in a personal capacity. The fund would probably require some form of secretariat. The best place for this is probably still the World Bank, but alternatives, such as a major international NGO, could be considered. A formal technical advisory committee would probably not be needed.

The three-tiered structure outlined above will rightly be seen as too simplistic and orderly to assume that it can implemented exactly as described in a world that is made up of highly diverse institutions, conditions, and political systems. It is not meant to represent a precise model that should be adopted in a linear manner. Instead, it attempts to provide an example of the way in which the principle problems now facing the national programs and international centers can be addressed.

Preparing for the Future: Issues to be Addressed

The foregoing text is meant to stimulate thinking and discussions about the future, not present a road map to it. There is no way that one small paper, written in isolation, can hope to adequately address all the problems the national and international agricultural research systems currently face—and present a definitive blueprint for solving these in the future. Rather, it is hoped that these individual views, when taken together with those expressed by the other contributors to this book, will raise issues that can then be addressed by wiser minds and by persons who have been more intimately associated with the CG system in recent years. Some of the questions that this discussion has raised, but not answered, include

- How to ensure that member countries would meet their financial obligations to the RAIs? The experience of the existing regional associations is not promising. They have largely been dependent on external funding and have faltered when such support ceased. In many cases, member countries have not paid the quotas to which they agreed.
- How would the larger NARS that do not become parts of the RAIs, or the residual components of NARS not subsumed into the new RAIs, overcome the institutional and personnel management problems listed above? Many of these can more readily be resolved in an international

rather than a national context. National institutions must find ways to stimulate better interinstitutional cooperation and change their laws and regulations to make it possible to management human and financial resources in ways that stimulate greater productivity.

- Should the products of the international centers, in the scenario described, be available only to those nations and private-sector companies that agree to contribute to their support? If so, what does this do to the concept of "international public goods" that is used to justify the use of foreign aid and other charitable contributions?
- How can the governing body of the fund for international agricultural research adequately reflect the views of the contributing members and the NARS while still remaining relatively small, agile, and free of excessive political influence?
- Which of the current IARCs should be converted to RAIs; which should make a portion of their facilities available to RAIs?

The issues that arise from this paper, as well as the other papers in this book, will not be easy to resolve. But they must be boldly addressed. Too much is at stake in the welfare of hundreds of millions of people around the world to do less. And they can be addressed. As men and women of good will put their minds together, it should be possible to design a global agricultural research system that will adequately meet the challenges and utilize the opportunities of the 21st century.

About the Author

John L. Nickel has a doctorate in Agricultural Entomology from the University of California, Berkeley. He taught and conducted research at that institution briefly; however, the bulk of his professional career was dedicated to agricultural research in developing countries. Over a 30-year period, he lived and worked in Paraguay, Honduras, Cambodia, the Philippines, Uganda, Nigeria, and Colombia. His management experience began in Uganda, where he served as dean of the Faculty of Agriculture at Makerere University for five years. He has worked in three IARCs: as a visiting scientist at IRRI for five months, as deputy director general of IITA for three years, and as director general of CIAT for 15 years (1974-1990). Since his retirement from CIAT, he has worked as a consultant in research management. In this capacity, he has worked with NARS in India, Indonesia, Mexico, Morocco, Nicaragua, Pakistan, Sri Lanka, and Uganda. He also chaired the TAC review of the CGIAR efforts in strengthening of NARS.

Global Research Systems for Sustainable Development

Vernon W. Ruttan

It is clear from even a casual reading of the papers in this book that the battle to achieve sustainable growth in agricultural production must be fought along a broad front. Poverty undermines health and degrades the environment. Environmental problems such as soil erosion, waterlogging and salinity, and fertilizer and pesticide residues link the agricultural agenda with issues such as malaria and schistosomiasis control, sanitation, and water and food quality. Environmental changes under way at the global level, such as acid rain, ozone depletion, and climate change, will require changes in food production at the producer and community levels.

> The central role of family- and community-level decisions in achieving growth in agricultural production and the enhancement of the resource base must also be recognized. This means that much more effective organizational and institutional linkages must be built between the suppliers of knowledge and technology and the users. It also means that institutions must be designed to place the users in a stronger role relative to the suppliers. A vision of the institutional infrastructure is needed to supply knowledge and technology in the areas of agricultural production, resource management, and health.* The process of evolving an effective global research system that will be capable of bridging the island empires of agriculture, environment, and health will not be easy. In his paper at the Bellagio Conference, Douglass C. North emphasized that the design of an institutional framework that will make sustainable agricultural development possible in the 21st century will require a clearer understanding of the way institutions evolve than is presently available.

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*The dialogues and recommendations are from three initial consultations, held under the auspices of the Twenty-First Century Project (Ruttan 1989; Ruttan 1990a; Ruttan 1990b). A revised version of the second consultation report has been published by Westview Press (Ruttan 1992).

Agricultural Research

Our vision is strongly influenced by the experience of attempts, beginning in the late 1950s, to establish a global agricultural research system (Ruttan 1986; Baum 1986). For the architects of the post-World War II set of global institutions, meeting world food needs and the reduction of poverty in rural areas were essential elements in their vision of a world community that could ensure all people freedom from hunger.

In the immediate postwar years, much of the burden fell on the FAO. But John Boyd Orr, the first director general of the FAO, burdened with the memory of the agricultural surpluses of the 1930s, was highly critical of the view that knowledge and technology represented a serious constraint on the capacity for agricultural production: "No research was needed to find out that half the people in the world lacked sufficient food for health, or that with modern engineering and agricultural science the world food supply could easily be increased to meet human needs" (Boyd Orr 1966:160). In the first two postwar decades, assistance for agricultural development in the poor countries was conducted largely in a technology-transfer and community-development mode.

The inadequacy of policies based on the technology-transfer or extension model led, in the late 1950s and early 1960s, to a reexamination of assumptions about the availability of a body of agricultural technology that could be readily diffused from countries or regions with high agricultural productivity to those with low productivity. The result was the emergence of a new perspective that agricultural technology, particularly yield-enhancing biological technology, is highly "location specific." Evidence was also accumulated to the effect that only limited productivity gains could be achieved by the reallocation or more efficient use of the resources available to peasant producers in poor countries.

The new vision that emerged as a guide to the sources of growth in agricultural production was the product of both experience with the improvement in agricultural technology and a reinterpretation of the role of peasant producers in the process of agricultural development.

It is apparent, in retrospect, that a number of colonial agricultural research institutes played an important role in increasing the production of several tropical commodities, particularly export commodities such as rubber, sugar, tea, cotton, and sisal. The Rubber Research Institute of Malaysia and the sugar research institutes in Barbados, Java, and India were important examples. The initial success of the Rockefeller Foundation's agricultural programs, initiated in 1943 with the establishment of the Oficina de Estudias Especiales in cooperation with the Mexican Ministry of Agriculture, was of more immediate relevance. The program focused on food crops important in Mexico, particularly wheat and maize, rather than export commodities.

In the early postwar development literature, peasant producers had been viewed as obstacles to agricultural development. They were viewed as bound by custom and tradition and resistant to change. In an iconoclastic work published in 1964, Theodore W. Schultz advanced a "poor but efficient" view of peasant producers. They were viewed as making effective use of the resources available to them. But they lived in societies in which productivity-enhancing, "high-payoff" inputs were not available to them.

Schultz, drawing on the experience of the Rockefeller Foundation program in Mexico and on case studies by anthropologists and agricultural economists, identified three high-payoff investments needed to enhance the productivity of peasant producers. These were (1) the capacity of the agricultural research system to generate locally relevant knowledge and technology, (2) the capacity of the industrial sector to develop, produce, and market new inputs that embodied the knowledge and technology generated by research, and (3) the schooling of rural people to enable them to make effective use of the new knowledge and technology.

These insights, from experience and analysis, shaped the response to the food crises of the 1960s and 1970s. The immediate response was the transfer of large resources, including food aid, to the food-deficit countries. The longer-term response was the mobilization of resources to develop a system of international agricultural research institutes and to strengthen national agricultural research systems.

In 1959 the Ford and Rockefeller foundations collaborated in establishing an International Rice Research Institute (IRRI) in the Philippines. This was followed by the spinning off of the international activities of the Rockefeller-supported Mexican maize and wheat programs to form the International Center for the Improvement of Maize and Wheat (CIMMYT) and the establishment of the International Institute of Tropical Agriculture (IITA) in Nigeria and the International Center for Tropical Agriculture (CIAT) in Colombia. In 1969 consultations were held among the Ford and Rockefeller foundations, the World Bank, FAO, the United Nations Development Program (UNDP), and several bilateral donor agencies, leading to the organization of the Consultative Group on International Agricultural Research (CGIAR). The initial membership consisted of the World Bank, FAO, and the UNDP as sponsors, as well as nine national governments, two regional banks, and three foundations.

By the early 1990s, the system had expanded from an initial four to 18 centers. The initial centers focused their research mainly on the major food crops grown in developing countries—rice, wheat, maize, potatoes, and cassava. These were joined in the 1970s by centers focusing on livestock production and animal disease, on and semiarid areas, on food policy, and on germplasm resources. In the late 1970s and early 1980s, research programs on crop and farming systems were developed to achieve more effective understanding of soil, water, climate, weed, and crop interaction. In the late 1970s, several donors to the CGIAR were instrumental in establishing independent research centers to work on soils, irrigation, and agroforestry.

As the new seed-fertilizer technology generated at the CGIAR centers, particularly for rice and wheat, began to come on stream, some donors assumed that the CG centers could bypass the more difficult and often frustrating efforts to strengthen national agricultural research systems. But experience in the 1960s and 1970s confirmed the judgment of those who had participated in the organization of the international centers that strong national research centers were essential if the prototype technology that might be developed at the international centers was to be broadly transferred, adopted, and made available to producers.

The location-specific nature of biological technology meant that the prototype technologies developed at the international centers could become available to producers in the wide range of agroclimate regions and social and economic environments in which the commodities were being produced only if the capacity to modify, adapt, and reinvent the technology was available. It became clear that the challenge of constructing a global agricultural research system capable of sustaining growth in agricultural production required the development of research capacity for each commodity of economic significance in each agroclimatic region. One response by the CGIAR donor community was the establishment of a new center, the International Service for National Agricultural Research (ISNAR), to provide analytical and planning assistance to national agricultural research systems in strengthening their organization and management. Another response, particularly during the 1970s, was substantially expanded support for national agricultural research systems.

Five new centers were added to the CG system during 1990–92, increasing the number of centers to 18. This expansion was not accompanied by an expansion of the resources available to the system, however, and support to the system since 1990-92 has actually declined in real terms, producing a "quiet crisis in the system."

The crisis has not only been financial. A number of the CGIAR centers have experienced the difficulties associated with organizational maturity. There is a natural life-cycle sequence in the history of research organizations and research programs (Ruttan 1982:132). When they are initially organized, they tend to attract vigorous and creative individuals. As these individuals interact across disciplines and problem areas, the organization often experiences a period of great productivity. As the research organization matures, however, there is often a tendency for the research program to settle into filling in the gaps in knowledge and technology rather than achieving creative solutions to scientific and technical problems. Since the mid-1980s the managers of several of the CGIAR institutes have been addressing, during a period of budget stringency, the problem of how to revitalize a mature research organization.

The CGIAR (as distinct from the set of centers it sponsors) has been successful in building highly valuable methods for surveying the worldwide agricultural research scene in relation to the needs for research results, reviewing ongoing research activities (both those of the international centers and of other institutions), and proposing changes in current research priorities and institutional arrangements, including, where necessary, the development of new research facilities.

Efforts to strengthen national research institutes have been only partially successful. The 1970s witnessed a remarkable expansion of agricultural research capacity in a number of developing countries. The national research systems in India, Brazil, Malaysia, and several other developing countries began to achieve world-class status in their capacity to make advances in knowledge and technology available to their farmers. A number of other countries, such as the Philippines, Colombia, and Thailand, achieved substantial capacity to conduct research on their major agricultural commodities. During the 1980s, the buffeting of a global recession and debt crisis had the effect of weakening the commitment of a number of aid agencies and national governments to strengthening agricultural research. In Africa, many national agriculture research systems that have received generous external support even during the 1980s have failed to become productive sources of knowledge and technology.

The role of technical support for decision making by farmers and the capacity to supply to producers the technical inputs in which the new technology is embodied have been continuing areas of controversy. In general the developing countries have been relatively extension intensive. The ratio of extension workers to agricultural product has been much higher in developing countries than in developed countries (Judd, Boyce, and Evenson 1987). Weak linkages between research and extension and between extension and farmers have represented a serious constraint on the diffusion of new technology. During the late 1970s and early 1980s, the World Bank devoted very substantial resources to the support of an intensive "training-and-visit" (T&V) system of delivering information about practices and technology to farmers. The system involved a highly regimented schedule in which the field-level worker was involved one day each week in intensive training about the information that he or she was to convey to farmers (Benor and Harrison 1977). In retrospect, it appears the system erred in placing the extension worker rather than the farmer, or the farm family, at the center of the technology adoption process.

A second constraint on the effectiveness of the transfer of agricultural practices and technology to producers is the weakness of the private sector as a source of both the supply and delivery of knowledge and technology (Evenson, Evenson, and Putnam 1987; Pray 1987). The emergence of more liberal economic policies since the early 1980s in a number of developing countries is, however, leading to rather rapid growth of private-sector suppliers of agricultural technology and to increased research by the suppliers.

The global agricultural support system is still incomplete. The deficiencies continue to deprive farm families of the support that they need to meet even current food-consumption and income needs. Yet the vision of the agricultural support system that will be needed to sustain growth in agricultural production is reasonably clear. During the past several decades, implementations of the vision have been less than adequate in some developed countries and in all but a few developing countries. With the ending of the cold war, it may now be possible to extend the vision to farm families in many of the formerly centrally planned economies. One important step will be to place farm families and the farm enterprise in those societies at the center of the agricultural production process. Another important step will be to link the agricultural research systems in the formerly centrally planned economies with the emerging global agricultural research system.

The Environment

If the global research system for agriculture now faces the challenges of maturity, then the global environmental research system still requires prenatal care.

To be sure, research for environmental conservation has a long and productive history in many parts of the world. Since World War II, this research has been given impetus and direction by at least three waves of concern over the implications of natural resource availability and environmental change for the sustainability of improvements in human well-being. Early work focused on the adequacy and protection of the material base for agricultural and industrial production. By the mid-1970s, increasing attention was also being given to the impact of residuals generated by that production on air and water quality and human health. Today, rapidly growing awareness of global change in the earth system has provided yet another dimension to our environmental concerns.

Most environmental research to date has been performed in universities, but national governments have become increasingly involved as supporters, producers, and users of environmental research. Over the last decade, there has also been an explosion in the number and variety of nongovernmental organizations active on the world's environmental scene, some of them producing research of the highest caliber and relevance (Livernash 1992). International programs for environmental research have also expanded dramatically since their "modern" birth in the International Geophysical Year of 1957. Nonetheless, most important international institutions for environmental research are barely 20 years old. Today's major research programs on global change—the World Climate Research Program (WCRP), the International Geosphere-Biosphere Program (IGBP), and the Human Dimensions of Global Change Program (HDGC)—are younger still (Jaeger and Ferguson 1991; Miller and Jacobson 1992; Perry 1991).

This impressive and expanding array of activities nonetheless falls far short of the global system of environmental research needed to provide the knowledge base for sustainable development. Still lacking is a coherent institutional structure that can link the world's environmental researchers both upward to the international level of policy negotiations and downward to the community-level consumers, producers, health workers, and extension agents on whose actions sustainable development must ultimately depend. In the wake of the Rio "Earth Summit," however, several initiatives are under discussion that could supply important components of such a system and move it substantially closer to reality.

The most ambitious of these is START—a System for Analysis, Research, and Training proposed in 1991 by the IGBP in collaboration with the WCRP and HDGEC. START is planned as "a global system of regional research networks to stimulate research, modeling, and training activities related to global [environmental] change in both the natural and social sciences" (IGBP 1992: 5). Its regional focus is based on the realization that global change wears local faces. The origins, the impacts, and the options for managing global environmental change will be different in different parts of the world, and must be understood within their local environmental and social contexts. The initial START planning document divided the world into 13 “scientifically coherent” regions (Eddy et al. 1991). Within each region, the research network is planned to consist of one or more research centers plus an unspecified number of regional research sites (for example, university departments and field stations). The networks aim to provide scientists from all parts of the world the knowledge and infrastructure necessary for them to participate fully in ongoing research concerning global environmental change.

Increasing attention is being given to the need for a permanent international research institution that could tackle environmental problems transcending individual regions and that could link national centers for environmental research into a truly global system. This function is currently performed on a largely ad hoc basis. But the time may well be ripe for complementing such efforts with a more permanent home or homes. The International Institute for Applied Systems Analysis, with its focus on problems of global change (IIASA 1991), has been put forward as one leading candidate (Maddox 1992). The Carnegie Commission on Science, Technology, and Government has proposed the establishment of a Consultative Group for Research and Environment, modeled on the CGIAR, that would combine the functions of resource mobilization, priority assessment, and research monitoring and evaluation in areas related to the environment.

However, it must be noted that in the dialogue leading to recent environmental research initiatives there appears to have been little consideration of appropriate linkages with agricultural and health research systems. This is a serious omission for two reasons. First, it virtually guarantees that many of the lessons painfully learned in the course of building today’s relatively mature network of agricultural and health research systems will be lost on the fledgling environmental effort. Second, it perpetuates the “island empire” problems referred to at the outset of this paper.

Lessons from the development of current agricultural and health research systems that should be incorporated in new environmental efforts reflect a growing appreciation of the central role of family- and community-level decisions in shaping sustainable development:

- Means must be designed to assure that research priorities reflect the environmental problems confronting individual families, farmers, and resource users in the field.
- We must resist the temptation to search for universal “silver bullets” that will solve specific environmental problems whenever and wherever they occur. Recognizing the need for simultaneous and complementary strengthening of local, national, and regional dimensions of the emerging global environmental research system is also required, and seems well embodied in the plans for START (Eddy et al. 1991). But a practical vision of “essential national environmental research”—how it is to be funded and linked to international efforts—is only beginning to emerge.
- A “technology-transfer” strategy for research and development will be no

more successful in dealing with environmental problems than it has been for sustaining improvements in agricultural productivity. In environment as in agriculture and health, the need is to enhance the voice and power of users relative to suppliers of needed research and development.

- An effective global environmental research system must be much more broadly inclusive than is presently the case. The need to better incorporate knowledge users in the system has been stressed here. The environmental R&D potential of the formerly centrally planned economies must also be tapped, although this will require institutional innovations to end the traditional exclusion of such societies from the "global" research system. Finally, the private sector must be encouraged as both a supplier and a deliverer of the knowledge needed for environmentally sustainable development. Perhaps no single factor has so inhibited the development of effective global research systems for agriculture and health as the failure to promote incentive and reward structures that can induce constructive private-sector involvement. In the environmental field, there is a vast potential for private-sector engagement in topics as diverse as energy efficiency and biotechnology. But a number of issues involving intellectual property rights, liabilities, and government-industry relations will have to be resolved before the potential can be fully tapped for the benefit of sustainable development (Schmidheiny 1992).

In summary, an effective global environmental research system will have many of the features of effective agricultural systems. The behavior of consumers of environmental services and of the producers of the residuals—households, farms, and factories—that erode environmental amenities will have to be recognized as central to the process of environmental change. The resources that will be needed to place households, farms, and factories in a position to respond constructively will depend on (1) the capacity of the environmental research system to provide the knowledge, including the essential national environmental research, needed by household, farm, and factory decision makers; (2) the capacity of national, regional, and community institutions to provide the knowledge, technology, and incentives to those who make decisions about resource use; and (3) the depth of understanding possessed by household, farm, and factory decision makers about the consequences of their own actions and the actions of the economic and political institutions in which they participate.

Bridging the "Island Empires"

We have argued that the "island empires" of the agricultural and environmental sciences can learn from one another as they strive to build global research systems that can support sustainable development. Whether they can, or even should, move beyond passive learning to active cooperation remains to be seen.

There seems little merit in any grand organizational scheme that would attempt to pull the already diverse networks of research in the respective empires under a single roof. And the most dynamic of the existing empires—that dealing with environmental research—simply does not have enough experience in the tough business of actually running a global network to seem credible as a leader of any major bridging movement. What does seem both feasible and desirable, however, is to begin some modest effort at active bridge building.

At a minimum, the principals of the island empires might agree to meet regularly—perhaps in the spirit of the G-7 summits—in order that they and their senior staff members could get to know one another and exchange information on current activities. An exploration of possible collaboration in global monitoring and other data-gathering activities might be a good early agenda item for such meetings. The UN Commission on Sustainable Development, established at the 1992 Earth Summit, would be one logical convener for such meetings. But private foundations and NGOs could do a lot to get the ball rolling.

At a deeper level, it is essential to realize that the global agricultural and environmental research systems outlined here have important common elements. They can be effective only as the underlying sciences—particularly the biological and the social sciences—advance. Advances in the biological sciences and the social sciences are necessary to enlarge the world's understanding of the natural and social phenomena in global change. They are also needed in order to expand the capacity to apply advances in knowledge to the natural and human dimensions of development in the poor countries, where most of the world's people live.

The need to enlarge scientific capacity in the poorer countries of the world should not be viewed as a burden on either the developed or developing countries. Rather, it is an opportunity to multiply the intellectual talent necessary to advance knowledge relevant to the achievement of sustainable development. Completion of the development of global research systems in agriculture, health, and the environment is a necessary component of a global effort to establish and mobilize the intellectual capacity and energy that will be needed to sustain development.

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About the Author

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The Changing Role of Science for Life on Planet Earth

Richard L. Sawyer

The role of science to serve life on Planet Earth is changing. The satisfaction humans have had as the important diseases of past generations, such as tuberculosis and polio were controlled and even eliminated is being replaced by a concern for new diseases. Science in the medical profession is faced with the emergence of AIDS and outbreaks of health problems that do not fit the pattern for any known diseases. Problems of animal health such as "mad cow" disease, with effects that may be passed on to humans, quickly become an international concern whenever an outbreak occurs. A good example of the changing role of science for food plants is late blight of potatoes, the disease that caused the "Irish potato famine" in the 1840s. Recently, a new strain of late-blight disease has appeared in major potato producing countries around the world with no adequate controls available.

During the "Irish famine," late blight caused the death of thousands of people and the migration of large portions of the population. Millions of dollars have been spent on both genetic and chemical research for the control of this disease. Until very recently, potato producers felt that science had produced adequate but expensive controls, and a recent "World Food Prize" was presented to a scientist who had been instrumental in the research accomplished. The new strain of late blight is now a threat to potato producers everywhere. It is particularly important to developing countries where potatoes have increased considerably as a food staple in recent years. Developing countries cannot afford the expensive chemical controls on which developed countries have learned to depend. The threat of late blight is also of concern to the entire fast-food industry, where most plates rely heavily on an important serving of inexpensive but highly nutritious potatoes.

The threat of late blight is causing both the private and public sectors of the potato industry to band together as never before to address the problem. National and international meetings of scientists are being held to plan strategies to address the problem. The International Potato Center (CIP) is developing a global late-blight initiative to address this new threat and has received permission from the CGIAR to raise whatever funds are necessary for the program.

A Changing Planet in a Changing World

The time has come for humans to recognize how much they are a part of an ever-changing system. The environmentalists who want to maintain this planet as it is today are working for a lost cause. Thankfully, they were not around during the ice age, trying to keep the planet as it was then. Hopefully, they will be able to help us better utilize our nonrenewable resources and maintain a balance of life on this planet so that humankind can gracefully adjust to changes about which little can be done. The destructive tools of war and their testing, the dependence on chemicals in food production systems and for everyday living, have placed humankind on a dangerous path that needs serious evaluation before we travel further.

The time has come to recognize that in the evolution of this planet, our climates will change and so also will the lives of animals, humans, and their foods. The role of science to address the needs of the global village must also change in order to maintain for as long as possible what is best for now and prepare for the adjustments needed by future generations. Advances in communication and transportation have rapidly pushed the Earth towards becoming a global village. A global approach by science must be developed now for a sustainable agriculture to adequately feed the rapidly increasing population of this village.

Pockets of Progress and Their Problems

Over the past 25 years, a number of developing countries with serious food production problems have made major advances in the development of local institutions to service agriculture. Much of this was triggered by help programs for developing countries that originated in North America and Europe along with private foundations. However, much of the progress has been cyclic and in many countries as foreign sources of funds have decreased, so has the agricultural science that has been started. USAID has been a major source of help to agriculture in many developing countries up until recently. Their present approach, however, is shifting from agriculture towards environmental and social welfare programs, partly due to pressure from developing countries for feeding the poorest of the poor. The attention given to the environment in recent years has shifted the interests of funding agencies away from agriculture.

Thirty years ago, funds were available to link many institutions in developed countries to specific programs being built in developing nations. Unfortunately, the sources of funds for such activities are no longer available, although the need still exists in developing countries and the desire to help still exists in developed-county institutions. Many of the past improvements in agriculture across the developing world were not linked to a sustainable economic system and have faltered as aid stopped.

The centers that are members of and associated with the CGIAR have been a major focus of help with research on food production in developing countries over the past 25 years. These centers have collected and safely stored the genetic resources for major food crops that are a resource to all countries. These gene banks will be essential to the development of new varieties to serve the changing needs for insect and disease control and the adaptation of varieties to changing climates for crop production on this planet.

The centers depend on annual grant funds for survival. Should the CGIAR system terminate, less than a handful of the 16 centers could probably survive. Few of the centers have developed the kinds of interdependencies and potential linkages essential for survival. A few years ago a study of training across the CGIAR system determined that centers would be remembered far more for their training of developing-country scientists than for any technology developed. Today the strength of centers into the future will probably be determined by their interdependent linkages with national programs and the private sector. If this be the case, then most centers are relatively weak today.

Until recently, the efficient utilization of natural resources such as soil and water has received very little attention in developing countries and also in many developed countries. The technology being developed by the international centers and also available for copying from developed countries will have little impact in large areas of the world until modern land-tenure laws are in place. The lack of title to land does not permit the accumulation of small lots into parcels of an economically feasible size, nor does it permit the borrowing of money from banks for farm improvements and proper production practices.

Water from expensive irrigation projects is inefficiently utilized in many countries and scarce water supplies are used to produce low-income crops with a high water requirement. Any vision into the future must coordinate technology development with the development of modern laws governing the use of natural resources so that new technologies will be applicable and will be used.

To help people adjust to the changes on Planet Earth, new tools are becoming available to agriculture. Biotechnology provides the opportunity to rapidly adjust present varieties to changing needs for disease and pest control. Scientists with vision could develop a backlog of material readily available to meet the changing needs for disease control such as is needed now for the new strain of late blight of potatoes. However, after over 10 years of publicity about the potential of biotechnology, the training of many scientists in using the new tools, and the large investments in facilities and programs by major agricultural institutions around the world, any real economic impact from these new tools is still probably 25 years away. In the early 1950s, irradiation received similar publicity. Its potential was never realized, partly due to lack of concentration around essential priorities and also because of the public fear of the effects of irradiation. Today a similar fear exists for the use of genetically transformed plants through the use of biotechnology.

A vision into the future must consider a system that provides links among the various capabilities available for a global approach and concentrates the efforts on priorities.

Biotechnology research in particular should be limited to priority needs and opportunities for an early economic return and should refrain from a dilution to the interesting as was done with irradiation.

Economic Development through the Improvement of Agriculture

Economic development through the improvement of agriculture is the major process by which most countries become developed in a sustainable way. Exploitation of a country's nonrenewable natural resources can be a step towards becoming developed. However, unless an adequate amount of the income from exported raw materials is invested in agriculture, the step is only temporary since eventually a country runs out of nonrenewable natural resources. Few developing-country politicians recognize the need for an adequate investment in agriculture from the national budget. Any vision into globalization of the agricultural research system of the future must take into consideration approaches to influence policymakers in developing countries to make adequate investments in agriculture from national resources and not to depend on the projects financed by foreign friends.

One approach to influencing political decisions for agriculture would be programs stimulating the emergence of a private sector with strong associations of agricultural professionals, organized to speak with a collective voice to agricultural needs. This voice could also be important in helping to orient the programs of public-sector institutions in agriculture towards priorities. Using Peru as an example, probably the greatest loss to the country during the agrarian reform in the late 1960s was the disappearance of agricultural associations that could speak collectively of their needs. In my opinion, the single most important factor today towards sustainable economic development in Peru would be an intelligent collective voice from the agricultural sector influencing political decisions. Excellent progress has been made in the country in sectors such as communication and transportation in recent years but agriculture has been neglected for almost three decades and left to the funding of projects by friends of Peru, which are usually oriented to the interests of the donor.

A Vision into the Future: A Step-by-Step Approach to a Global System

A vision into the future and the development towards a global system should start with the facilities and capabilities already in hand. Values and opportunities must be recognized along with limitations. The international agricultural research centers already exist with excellent facilities, staff, and communication linkages with public-sector agricultural scientists around the planet. These centers are the best possible focal point around which to start to organize a global approach to agricultural science for sustainable food production for the planet. However, these centers are at the mercy of annual grants from donors. An excessively bureaucratic structure is in place for their management. They have few linkages into the private sector and little interdependence established with national programs in either the developed or developing countries. A vision on the role of these centers in a global approach must take into consideration alternatives for removing these present limitations. There is resentment in many national institutions for the somewhat isolationist approach of most center programs. The token approach for developing countries to be involved in decision making at the level of the CGIAR system is far from adequate.

Good scientific capabilities exist in both developed- and developing-country national programs that can be used for the changing needs of the global village. In the early days of the CGIAR system, many of these national programs had good linkages to international research centers. In recent years, due to funding availability and the changing priorities of center programs, many capable national scientists feel that they have been left waiting on the sidelines. Resources available for their international involvement are scarce and they are frustrated that their capabilities have not been used. In the early days of the CGIAR, CIP used core funds for contracts with scientists in both developed and developing countries whenever equally excellent capabilities were available for essential research. In recent years, however, funding reductions have caused this contract research to be reduced considerably, with a resulting loss of valuable scientific linkages and the accumulation of resentment in some national programs.

The private sector has started to make some major progress in the use of biotechnology. They need the genetic resources of the international centers and the capabilities for testing materials by national scientists in their different environments. Biotechnology could start to trigger a systems approach by various essential elements already in place but which need a mechanism for the linkages. A vision into the future should look at such potentials and search for other alternatives for triggering interactions leading to sustainable relations.

A major missing link in the development of a global system for agriculture is the absence of priority setting around long-term comparative advantages for the production and marketing of crops in major international markets. Institutions across the developed world are copying each other in this area, and developing-country institutions are doing the same. An essential first step in the development of the global system is for each country and region to identify long-term comparative advantages that its natural resources and climates provide to serve both local and global village markets. Once these have been identified and accepted by the agricultural sector, the national institutions and organizations in both the public and private sectors should concentrate programs of research, training, and extension on the production and marketing of those products for which a long-term comparative advantage exists. The decisions of policymakers and the programs of agricultural institutions should be aimed at ensuring that a competitive advantage exists for the products for which the climate provides a comparative advantage.

Summary

Many of the essential elements are already in place for the development of a global approach to the changing needs in agricultural science to serve life on Planet Earth. What is missing are essential linkages between public-sector institutions in developed and developing countries and between the public and private sectors of agriculture in both national and international programs. The CGIAR system of international agricultural research centers is an excellent starting point for developing the global approach. However, the process would have to permit all participants to have a well-considered voice in decision making for the global approach. The research centers would be only a part of the approach with a specific role to play.

A committee composed of interested and dedicated people, who have the vision to determine what is needed and potentially possible at a future point of time, is the beginning. The present situation for agriculture in general and for problems such as late blight of potatoes clearly indicates that the balance between doers and visionaries in recent years needs adjustment. There have been too many doers and not enough visionaries anticipating changing needs, determining the direction for agriculture, looking for alternative approaches, and planning strategies to achieve desired results. Development programs in recent years have attracted valuable leaders who are able to get things done under difficult conditions. The vision for what is being done and goals towards which programs are working is not evident, although the ability may be present in a system that provides little opportunity for its use.

Programs for the changing role of science for life on Planet Earth will require a continuity that probably will not come from a dependence on annual grant funds by donors whose interest span is limited. Mechanisms need to be identified that will help lead to long-term economic security for operations in a relatively short time.

About the Author

Richard L. Sawyer is director general emeritus at CIP. He was a professor in vegetable crops at Cornell University from 1953 to 1966, then went to North Carolina State University where he was a professor of horticulture and national potato-program leader in Peru from 1966 to 1972. He was the founding director general of CIP in 1972, serving in this capacity until 1991. His present responsibilities include president of Fundación Perú, chairperson of the IBSRAM board, member of the APUKI advisory panel, and consultant for ABSP at Michigan State. Selected honors received include the Leonard H. Vaughn ASHS Award in 1957; Doctor of Science, University of Maine, 1976; Honorary Professor, Chinese Academy of Agricultural Sciences, Peking, 1990; Life Achievement Award, Potato Association of America, 1990; Doctor Honoraris, Universidad Nacional Agraria La Molina, Lima, 1996;

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Agriculture as an Engine of Economic Development

G. Edward Schuh

Agriculture is in danger of falling off the agenda of the bilateral and multilateral development agencies. It also continues to receive low priority on the part of governments in the developing countries.

This decline in the importance of agriculture on development agendas appears to be due at least in part to a misunderstanding of how agriculture contributes to economic development, and a failure to recognize what a powerful engine of economic development it can be, especially in the early stages of economic development. It also appears to be due to a failure to recognize some of the positive income-distribution features of promoting economic development through the modernization of agriculture.

This paper discusses these issues. It begins with a discussion of what appears to be the conventional view about agriculture in the development process. It then addresses how the modernization of agriculture can contribute in a positive way to broader economic development. This is followed by the role of food as a wage good and how the modernization of that sector can contribute to helping a country be more competitive generally in the international economy. The final section discusses an important opportunity many developing countries have if they take steps to shape their comparative advantage in favor of agriculture. At the end there are some concluding comments.

The Conventional View of the Role of Agriculture in Economic Development

The prevailing view about the role of agriculture in economic development appears to be based on an incorrect interpretation of two important facts about that sector as economic development proceeds. The first fact is that agriculture's share of a nation's gross domestic product (GDP) declines as the economy develops and per capita incomes rise. The second fact is that the share of the total labor force that agriculture accounts for declines under these same circumstances.

Policymakers and developers appear to conclude from these inevitable consequences of economic development that the way to promote economic development is to facilitate such long-term trends. This is to concentrate on the symptoms or consequences of development, in contrast to understanding the underlying economic and technological forces at work.

Agriculture declines both as a share of the GDP and of the labor force as a consequence of some basic features of the food sector. Food tends to have a low income elasticity of demand, which is to say that as per capita incomes rise, the demand for food does not rise as much as the demand for other goods and services. This is rooted in what economists refer to as Engel's Law: the empirical fact that as per capita incomes rise, consumers spend an ever smaller share of their budget on food.

These demand considerations mean that under rather general conditions, food and agriculture as a sector of the economy will decline as the economy grows and develops. This process will be accelerated if new technology that raises productivity in the sector is introduced. This increase in productivity will, in turn, contribute to the release of capital and labor from the sector as output expands against a demand that is rather unresponsive to increases in per capita incomes.

None of the above means that the food and agriculture sector should be neglected as the means of promoting economic development. To the contrary, we will explain in the following sections how the food and agriculture sector can play a significant role in promoting general economic development.

How the Food and Agriculture Sector Contributes to General Economic Development

The food and agriculture sector can contribute to general economic development in very positive ways if the development of the sector is based on the development of a capacity in research and extension to develop and deliver new production technology to the sector, and if economic policies are such as to promote the adoption of that new technology. It is useful to consider two distinct cases: the modernization of the subsistence or staple sector and the modernization of the export or import-competing sectors.

The subsistence or staple sector refers to the bundle of commodities that constitute the main food items for consumers. In most countries this includes such commodities as rice, maize, cassava, potatoes and other tubers, edible beans, and sorghums and millets. These commodities tend to be called *necessities* since they are so essential to providing the caloric intake of the consumer, especially the low-income consumer. An important feature of the conditions of demand for these commodities is that not only is the demand for them relatively unresponsive to increases in per capita income, but the quantity demanded is also relatively unresponsive to changes in their price. That is in part why they are referred to as necessities. These commodities tend to be relatively important in the budget of low-income people.

Consider what happens when a new, yield-enhancing technology is introduced into the production of these commodities. This technological change will increase the supply of these commodities, a process which will continue as the adoption of the new techniques spreads among an ever-larger number of farmers. Because of the unresponsiveness of price to changes in supply, the price of the commodity will tend to decline. Such commodities tend not to be traded internationally by low-income countries, with the result that the price tends to be determined by conditions of domestic supply and demand.

This decline in price, although it will be disadvantageous to farmers who do not adopt the technology, has a very positive effect in the economy at large. The decline in price of an important staple constitutes an increase in the real income of the consumers who consume the staple. Although the increase in income for each consumer may be relatively modest, when summed over the entire economy, the total increase in income can be substantial. That is one of the reasons the social rate of income to investments in research that lead to new production technology tends to be so high.

There is another important feature of modernizing the production of subsistence or staple commodities. The benefits of the new technology tend to be distributed disproportionately in favor of the poor. That is because poor consumers tend to spend a larger share of their budget on food than do middle- or upper-income consumers.

This distribution of the benefits of economic development in favor of the poor is a very important characteristic of the development of agriculture from the introduction of a new production technology. In fact, one can identify no other sector of the economy that has this characteristic, nor for which the benefits are so widely distributed in the economy. The reader can gain insight into this by considering the distribution of benefits from developing an automobile industry or other goods and services whose demand expands more rapidly as per capita incomes rise. Relatively few people will be benefited, and they will tend to be the middle- and upper-income groups.

The benefits of modernizing the subsistence or staple sector does not stop there, however. The widespread increase in per capita incomes will generate an increase in demand for goods and services, the demand for which will increase in a relative way as those incomes rise. That increase in per capita incomes will induce an expansion of the nonfarm sector. Thus, the benefits of the modernization of agriculture will be spread to the rest of the economy in successive waves.

Now consider the introduction of a new production technology into the tradable sectors. There are two components to this sector—the export sectors and the sectors that compete with imports. The contributions of the modernization of each of these sectors are somewhat different, in large part because the demand for these commodities is substantially different than the demand for subsistence commodities. Because these tradable sectors are part of the international economy, increases in supply have very little effect on the price of the commodity.

Although the benefits from the introduction of a new production technology into the sector are somewhat different, the modernization of these sectors can also be powerful sources of more general economic development. In the case of exportable commodities, farmers rather than domestic consumers will tend to receive a major share of the benefits of the new technology. The prices they receive will not decline, other things being equal, but they will have an increase in output due to the increase in productivity the new technology makes possible.

Although this will benefit the agricultural sector, it is not the end of the story. The increased productivity will make producers more competitive in international markets, and the increase in supply that the increase in productivity makes possible will, in turn, increase the volume of exports. The net effect will be an increase in foreign-exchange earnings. This increase in foreign-exchange earnings can be used to service foreign debt, or to finance a higher rate of economic growth. If the latter, the benefits will again be distributed rather widely in the economy, although not as widely as in the case of subsistence commodities. However, the new jobs that are created can have more widely felt spillover effects in the economy.

The effects of introducing a new production technology into import-competing commodities is basically the same, although with one important difference on the foreign-exchange side. Rather than increasing foreign-exchange earnings, in this case it saves them since the need for imports will decline. Those savings, however, can be used to service foreign debt or to finance a higher rate of economic growth in the same way as an increase in foreign-exchange earnings from an increase in exports can be used.

In conclusion, we can see that the development of agriculture through the introduction of a new production technology can be a powerful engine of economic growth. Its benefits will be widespread in the economy, generally in favor of low-income groups. Investments in agricultural research and extension to develop and distribute new production for farmers has a high social rate of return. In fact, extensive research has shown that these rates of return range all the way from 35 percent to over 100 percent. Those are handsome rates of return, especially when developing countries can borrow from the World Bank and other development agencies at rates of less than 10 percent. Distributing the benefits of economic development in favor of the poor also tends to be a goal of policymakers.

Food as a Wage Good

The allocation of development resources to the modernization of agriculture, and especially to the subsistence sector, also has more general positive benefits in the economy. Food constitutes an important wage good. Workers tend to spend a large share of their budget on food. Thus, the decline in the price of food results in an increase in the real wage rate for workers so long as the nominal wage does not change.

It is useful to think about the consequences of this in the context of the need for an economy to remain competitive in the international arena. Two factors tend to play significant roles in shaping international competitiveness: the real exchange rate for the nation's currency and the cost of labor, which is determined by both the wage rate and the productivity of the labor.

Let's for present purposes focus on the cost of labor. One can think about it from two different perspectives. First, with food prices declining, the nominal wage can decline with no reduction in the real wage. This will help the country to be more competitive in the international economy. The effects of this can be widespread in the economy, thus increasing foreign exchange earnings and helping to finance a higher rate of economic growth.

Second, the nominal wage rate can stay the same, with the result that the real wage will increase in the domestic economy. In this case, workers will be benefited with higher real wages instead of through increased employment.

How the benefits from the modernization of agriculture are distributed under these two circumstances will be very different. Which of the two scenarios is realized, or whether it is some combination of the two, will depend on the competitiveness of the economy as a whole and the competitiveness of the labor markets themselves.

In any case, the role of food as a wage good is another important means by which the modernization of agriculture—by the introduction of a new technology into the sector—can contribute to the general development of the economy as a whole.

An Opportunity

The developing countries have an important opportunity to earn increased foreign exchange if they are willing to modernize their agriculture. The current situation is that comparative advantage is shifting in the international economy, with the advantage for agriculture shifting to the developed countries.

The reason for this shift is that the developed countries have the installed capacity for agricultural research and thus can continue to produce a steady stream of technology for that sector. For the most part, however, the developing countries lack such capacity. What they have to their advantage is that the technology for the manufacturing sector can be readily transferred to their economies, in contrast to agricultural technology. In addition, over recent decades the developing countries have been increasing their level of general education, which makes it possible for them to adopt new technologies from abroad for their labor-intensive manufacturing sectors.

The issue that is likely to emerge in the future is that the continued growth in the world's population and the potential for increases in per capita incomes in the developing countries makes it likely that the demand for food will be strong in the future. The issue of whether the developed countries will be able to meet this increased demand is open. If they cannot, developing countries that begin today to develop their capacity for agriculture will be able to capitalize on the agricultural markets of the future.

Concluding Comments

To conclude this paper, it is useful to return to a point made near the beginning. It is true that a country should want to see its agriculture become an ever-smaller part of the general economy. That is in effect the mark of a developed economy since it indicates that most of the productive capacity of the economy is being used to produce the goods and services associated with higher levels of per capita incomes.

The issue is how to bring that transformation about in an efficient and equitable manner. The implications of the analysis contained herein is that the way to do it is to invest in modernizing the agricultural sector. Agriculture can be the engine or driving force for general economic development, with the social rate of return from investments to this end having a very high payoff, while the benefits of the development are distributed in favor of the poor.

The modernization of agriculture requires, critically, the development of a vital agricultural research and extension system, the education of the rural population, and the access by farmers to modern inputs such as fertilizer and pesticides at reasonable prices. It also requires favorable economic policies that provide the incentives for farmers to adopt new technologies.

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Uncommon Opportunities for Achieving Sustainable Food and Nutrition Security: An Agenda for Science and Public Policy

M. S. Swaminathan

We call upon the world leaders assembling at the World Food Summit convened by FAO in Rome in November 1996 to adopt this agenda as a means of harnessing science and technology for the transformation of agriculture into a primary instrument of a global *Evergreen Revolution*. Based on the principles of ecology, social equity, energy efficiency, employment generation, and economic viability, this revolution will provide the technical foundation for the universal eradication of hunger and the achievement of a food- and nutrition-secure world for all. At the same time, we wish to emphasize the urgent need for adoption, particularly by developing countries, of population policies that can ensure that children are born for happiness and not just for mere existence.

A New Revolution in Agriculture

In the over 50 years since FAO took up the challenge of "food for all," never before has science offered a greater opportunity to achieve this goal for even the poorest of the poor. Scale-neutral innovations, including those emerging from the fields of biotechnology and information technology, as well as the holistic management systems of soil health care, conjunctive water use, integrated pest management, and integrated intensive farming systems represent only a few of the new opportunities to reach the nearly 800 million people lacking adequate nutrition.

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Tapping this unprecedented potential will depend upon strengthening the capacity of national agricultural research and development systems to respond to these new challenges with creativity. Therefore, we urge world leaders to reverse the global trend of disinvestment in agricultural research and development, convinced that such a short-sighted policy can but only have tragic results. At the same time, limited resources make prioritization of research initiatives essential, and it is intended that this agenda assist political leaders in that task.

Meeting the challenge of increasing food availability now and in the future demands equal focus on production systems and on the larger issues of access to food. Therefore, science must work in partnership with farmers to create a new agriculture. An Evergreen Revolution must bridge the gap between the past's gains in production and the persistent need for reliable access to food by all. This will require a number of innovative approaches, including the following:

- transformation of the most marginalized farmers of the world into agents of poverty alleviation and environmental management through the blending of traditional and frontier technologies in socially equitable, economically viable and environmentally sustainable *ecotechnologies*;
- production of more food from a diminishing resource base, requiring new agricultural technologies and management systems providing *increased productivity* per unit of land, water, energy, labor, and investment. Part of this will involve focusing research on neglected crops such as minor millets, grain legumes, and tubers, which can perform in times of environmental stress and in neglected areas such as arid and semi-arid coastal and mountain areas;
- development of a system's approach marshaling the combined and coordinated efforts of physical scientists and agricultural researchers, as well as systems analyst mathematicians and social scientists. While agricultural production will remain the foundation of food and nutrition security, the larger scientific framework must integrate postharvest technology, distribution systems, and rural development, as well as economic and social empowerment of the poor, especially women. This holistic approach must also be taken in restructuring administrative systems, leading to a high degree of professionalism of such services.

Eliminating hunger among the poor of all nations will depend upon tapping the new opportunities offered in these unconventional approaches. Such uncommon opportunities are rooted in a new and broader conception of food and nutrition security, which integrates multiple physical, social, economic, and environmental dimensions.

National policies for sustainable food and nutrition security

National policies for sustainable food and nutrition security should ensure that

- every individual has *physical, economic, social, and environmental access* to a balanced diet that includes the necessary macro- and micronutrients, safe drinking water, sanitation, environmental hygiene, primary health care, and education so as to lead a healthy and productive life;

- food originates from efficient and *environmentally benign production technologies* that conserve and enhance the natural resource base of crops, animal husbandry, forestry, inland and marine fisheries.

The principal operational implications of the mission statement given above are the following:

- The *physical dimensions* of food and nutrition security will involve a transition from chemical- and machinery-intensive to knowledge- and labor-intensive farming technologies.
- The *economic dimensions* of food and nutrition security require the promotion of sustainable livelihoods through multiple income-earning opportunities such as crop-livestock-fish integration and agroprocessing and agribusiness.
- The *social dimensions* of food and nutrition require addressing gender, class, and ethnic discrimination against marginalized sectors of society, who consequently tend to be the most food and nutritionally insecure.
- The *environmental dimensions* of food and nutrition security involve attention to soil health care, water harvesting management, and the conservation of biodiversity, as well as to sanitation, environmental hygiene, primary health care, and education.

Ultimately, self-reliance and skill- and labor-intensive technology must be the basis of food and nutrition security. As agriculture provides most of the jobs in many developing countries, the import of food by these nations would be equivalent to importing unemployment.

A Ten-Point Scientific and Public Policy Agenda for Sustainable Food and Nutrition Security

The following 10-point agenda can provide the basic scientific and policy framework for achieving sustainable food and nutrition security at both the national and international levels.

1. *An Evergreen Revolution must increase output in an economically viable, socially equitable, and environmentally sustainable manner,* focusing on the food and nutritional supply system as a whole. Beyond investing in new scientific technologies, this will require public policies that provide a supportive economic and social environment.
2. *Science and technology for public good is the key to improving agricultural productivity* among the poor. With the spread of a culture of free markets and intellectual property rights, it is essential that science designed for the public good receive adequate political and financial support. Scientists working in the areas of food and health security should regard themselves as trustees of their intellectual property.

3. *Sound environmental policies must provide the foundation of agricultural sustainability.* Therefore, a national natural resource conservation and enhancement strategy will be fundamental to a national food security system. High priority must go to combating desertification and deforestation, and to restoring degraded land.
4. *Entitlements, asset reform, and technological empowerment of the poor will be essential in ensuring economic access* to balanced diets and would help address the triple goals of natural resource conservation, poverty alleviation, and food security.
5. *The gender perspective must be integrated into technological development and dissemination.* A gender code, to identify and evaluate actions that ensure equity in food and nutrition security, should become an integral part of agricultural research programs.
6. *Agriculture must serve as an instrument of income and livelihood opportunity* as well as of food production. Therefore, it is important that the economic benefits of agroprocessing and agribusiness be taken to poor families through rural value-added enterprises and partnerships with the private sector.
7. *Macroeconomic policies in the areas of pricing, trade, and investment should be based on environmental sustainability as well as gender and social equity.* A systems approach must be taken, with a holistic view of production, distribution, and consumption.
8. *The information age has provided tools such as the Internet and GIS mapping to promote a learning revolution in agriculture.* Extension information should be disseminated through computer-aided information shops operated by village youth. Vocational polytechnic institutes may be established for the rural poor.
9. *Existing global conventions must be implemented,* including those on climate, biodiversity, desertification, and the oceans, as well as Agenda 21 of UNCED and the global plans of action on population, gender, habitats, social development, and plant genetic resources.
10. *Public policies for sustainable food and nutrition security must institutionalize procedures to focus on both production and access.* To achieve this, it will be prudent to develop legislation based on the principles outlined below.

A. National Sustainable Food and Livelihood Security Act

This should include provisions for the following:

- promoting policies that can help to achieve a balance between human and animal populations and the supporting capacity of the ecosystem;
- promoting conservation and enhancement of the natural resource base;
- rehabilitating degraded soil, forests, and aquatic resources and introducing scientific land- and water-use policies;
- ensuring economic and social access to food through steps that can enhance the livelihood security of the rural and urban poor, with special attention being given to children, orphans, and women;

- improving the biological absorption and retention of food through attention to sanitation, environmental hygiene, and primary health care;
- ensuring universal literacy and *techniracy* (i.e., imparting new technical skills through learning by doing) for both men and women at the village level;
- promoting the development and dissemination of ecotechnologies at the production and postharvest phases of farming, with special attention to waste treatment and recycling;
- improving postharvest technologies, including storage, non-CFC-based refrigeration, packing with biodegradable material, and efficient transportation and delivery;
- establishing input and output pricing and credit and insurance policies that can help all farm families, irrespective of their innate input-mobilizing and risk-taking capacity to benefit from new technologies and marketing opportunities;
- building and maintaining grain reserves and operating an efficient public distribution system for making essential commodities available at affordable prices to the poor;
- developing a *hunger-free area program* in cooperation with local communities in order to demonstrate that chronic hunger and malnutrition can be overcome speedily by creating an enabling environment, where every individual earns his or her daily bread.

B. Implementing the equity provisions of the Biodiversity Convention

Industrialized nations should contribute *0.01% additional ODA* to be credited to a global fund for biodiversity for sustainable food security. Such a fund can be handled as a trust fund under the Global Environment Facility (GEF) for implementing the Global Plan of Action adopted at the International Technical Conference on Plant Genetic Resources held at Leipzig in June 1996, and for recognizing and rewarding the contributions of indigenous and rural women and men to the conservation and enhancement of biodiversity, that is, Farmers' Rights. It should also be used to safeguard all mega-biodiversity areas as well as "hot-spot" locations with reference to threats to biodiversity, ranging from landscapes to individual species. In addition, developing nations rich in agrobiodiversity should levy a one percent cess on all agricultural produce for this purpose, to be credited to a national community gene fund. This fund could be used to recognize and reward the contributions of tribal and rural families to the in situ conservation and enhancement of agrobiodiversity. Such steps will help to restore and revitalize the on-farm genetic-conservation and -selection traditions of rural communities.

The Role of the International Community

To maximize efficiency and the return on investments in the Evergreen Revolution, South-South partnerships and cooperation in research and development will be essential, especially among nations with related agroecologies. The CGIAR centers should support these emerging regional networks and national systems, pursuing a policy of subcontracting present responsibilities as appropriate. We, the Summit participants, resolve to establish an *International Scientific Steering Committee for Sustainable Food and Nutrition Security,* to provide political leaders with the scientific framework necessary to achieve food for all. Broader consensus can be fostered through a *Global Coalition for Sustainable Food Security* that would include farmers' organizations, civil societies, academia, the corporate sector, service organizations, and the mass media.

To convert the rhetoric of "food for all" into reality within a specified time frame, we urge the G7 and G15 countries to jointly establish a high-level *Steering Committee for Sustainable Food and Nutrition Security,* for which FAO could provide the secretariat. This unique political body would be fundamental in reaching the shared goals of global food and environmental security, reduced need for emergency aid, enhanced political stability, and the development of new markets for trade. This is a responsibility that the political leaders of the G7 and G15 countries must accept at the November, 1996, World Food Summit, if we are to enter the new millennium with hopes for a more humane world.

Participating academies

African Academy of Sciences
Arab League Educational, Cultural and Scientific Organisation
Caribbean Academy of Sciences
Chinese Academy of Sciences
Hungarian Academy of Sciences
Kenya Academy of Sciences
Lithuanian Academy of Sciences
National Research Council, Canada
National Academy of Agricultural Sciences of India
National Academy of Madagascar
National Academy of Sciences, India
National Academy of Sciences, Italy
Pakistan Academy of Sciences
Third World Academy of Sciences
Uganda Academy of Sciences

Participating governments

Government of India
Government of Italy
Government of Tamil Nadu

Participating intergovernmental organizations

Consultative Group on International Agricultural Research
Encyclopaedia of Life Support Systems
Food and Agriculture Organization of the United Nations
United Nations Educational, Scientific and Cultural Organisation
United Nations Development Programme
United Nations Environment Programme
United Nations Fund for Population Activities

About the Author

M. S. Swaminathan completed his PhD in genetics at the University of Cambridge in 1952. Since then he has worked actively as a researcher and teacher in the fields of wheat and rice breeding and improvement. Between 1972 and 1982, he served as director general of the Indian Council of Agricultural Research, as well as secretary of agriculture and member of the Planning Commission of India. He served as director general of the International Rice Research Institute from 1982 to 1988. He is a fellow of the leading science academies of India and of many countries in the world, including the Royal Society of London and the US National Academy of Sciences. He has received 34 honorary doctorates from universities around the world. He received the first World Food Prize in 1987. He served as independent chairperson of the FAO Council between 1981 and 1985 and was president of the International Union for the Conservation of Nature and Natural Resources (IUCN) from 1984 to 1990. He currently holds the UNESCO Chair in ecotechnology and is chairperson of the M. S. Swaminathan Research Foundation, which has been chosen for the 1996 Blue Planet Prize.

The Globalization of Agricultural Research: A Case Study of the Control of the Cassava Mealybug in Africa

L. D. Swindale

The cassava mealybug (*Phenococcus manihoti*) first appeared in Africa in Zaire in 1973. It came from Latin America, and because it had no natural enemies in Africa, its effects were devastating. By 1977, when the government of Zaire contacted IITA for help, the mealybug had spread to Gambia and Senegal, and there were estimates that as much as 80 percent of the crop was being lost. At a workshop held in Zaire, two strategies were agreed upon: one, to breed resistance to the mealybug in the cultivars of cassava in use in Africa and, two, to search for and introduce parasitoids or predators specific to the cassava mealybug from the tropical Americas. Cassava in Africa is preponderantly a small-holder and subsistence crop grown in small, widely dispersed plots throughout the continent, and chemical control seemed unlikely to succeed.

Most of the resources immediately available were assigned to the plant breeding approach. The biological control program commenced with one scientist and a Zairian postdoctoral fellow working in one corner of an IITA greenhouse.

The cassava mealybug was scientifically described in 1977 by D. Matile-Ferrero, of the Paris Natural History Museum, working in Congo. The International Institute of Biological Control (IIBC) undertook explorations in the Caribbean and northeastern South America where cassava mealybug was thought to occur, although it was not considered a major pest. Natural enemies of the mealybug were gathered, passed through quarantine, and tested in Zaire and Senegal without success.

The mealybug continued to spread throughout Africa. Scientific studies undertaken in research institutions throughout the affected region and coordinated by IITA gathered basic information about cassava and the biology and ecology of the mealybug. Entomologists in Congo, Zaire, Nigeria, and Gabon discovered that the natural enemies of other mealybugs were beginning to feed on *P. manihoti* without significantly reducing its numbers. A revision of the genus *Phenacoccus* was undertaken by the CABI International Institute of Entomology.

In 1980 IITA and CIAT, where the CGIAR's global program of research on cassava is located, joined actively in the search and exploration. A visit by Dr. Herren (who was involved in the initial studies at IITA) to CIAT quickly led to the realization that the mealybug in the northeastern regions was not *P. manihoti*. The scientists turned to other regions of the continent, and in 1981, Dr. Anthony Bellotti of CIAT discovered the elusive mealybug in Paraguay. IITA followed with biological and ecological studies of the host and its natural enemies.

The parasites of this mealybug were collected and sent to IIBC where tests were undertaken to verify that they were specific to the cassava mealybug and would not attack any other insect or carry diseases. In subsequent field tests at IITA by Dr. Herren, one of the many species introduced, a tiny wasp (*Epidinocarsis lopezi*), was found to be highly effective.

Dr. Herren and his colleagues then embarked upon a program to rear large numbers of the wasp and to devise methods for its dissemination throughout the cassava-growing and affected areas of Africa. First releases were made in southeastern Nigeria. After five months, the wasp was collected 100 miles from the release site. A full-scale release program ensued. Most of the wasp releases were made by hand on the ground, but for speedy delivery in remote areas and particularly because the wasp had a short life span, an aerial release technique was devised with the assistance of engineers from Austria.

Between 1981 and 1990, the wasp was released in more than 100 locations in 25 countries from Senegal in the northwest to South Africa in the southeast. The wasp became established over an estimated area of 2.7 million square kilometers. Its distribution exceeds that of any other biological agent introduced into Africa for biological control of insect pests.

Figure 1, taken from a 1991 paper by Dr. Herren, gives an idea of the global spread of research institutions involved in this hugely successful application of the principles and practices of biological control. Lack of space limits the number of participating institutions that can be shown in the figure. In all, 23 universities and 24 research institutions and national biological control programs were involved along with IITA and CIAT.

By 1994, the costs of the project were estimated by IITA and the University of Hohenheim to be of the order of $27 million. The benefits, in cassava yields at farm-gate prices, were of the order of $4.5 billion. And these benefits were gained almost entirely by small-holders and subsistence farmers and their families! There have been no adverse environmental consequences.

Support for the project was almost as global as the research. The aid agencies of Austria, Belgium, Canada, Denmark, France, Germany, Italy, Norway, Sweden, Switzerland, The Netherlands, and the European Union, the African Development Bank, FAO, IFAD, UNDP, and of course, the CGIAR contributed to the work either through IITA or independently. Only about 5% of the funds used came from the core program of IITA. The funding was organized by a donor sponsoring group convened by IFAD. Once or twice a year an expert

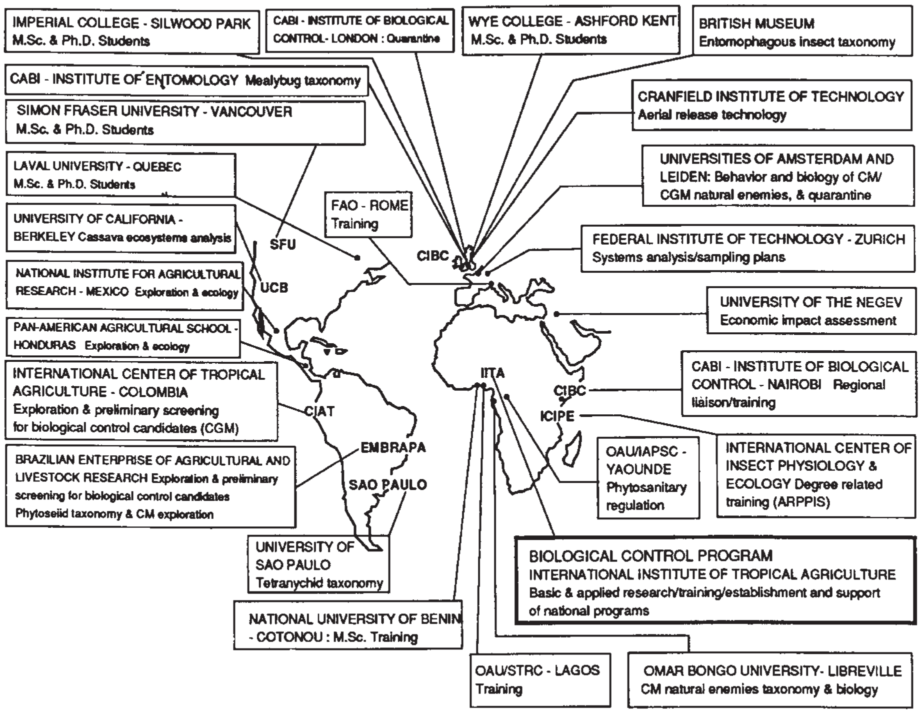

Figure 1. Schematic representing the global involvement of institutes in research on controlling the cassava mealybug in Africa

advisory panel established by the donor group met to conduct reviews and provide general oversight of the program.

In 1977, there were few entomologists in Africa with experience in biological control or integrated pest management. By 1990, 430 people from African biological control programs had been trained, and degree-related training carried out at IITA and ICIPE had resulted in 20 MSc degrees and 18 PhDs being awarded by universities in Africa, Europe, Canada, and the USA.

In answer to specific questions, Dr.Herren stated:

- About 60 scientist-years were used in the project up to 1994.
- Nearly all of the cooperators and collaborators received funds from the project to cover all or part of their costs. ORSTOM and the government of Zambia paid the costs of their participation. All the countries involved contributed the time of their entomologists to the biological control program.
- Overseas cooperators were selected based on the specific research needs of the program. A few examples: the University of California at Berkeley and the Federal Institute of Technology in Zurich were included for their know-how in plant/insect models; the International Institute of Biological Control for its expertise in insect quarantine; EMBRAPA for its location and needed support for the exploration for natural enemies; and

the University of Leiden for its expertise in insect biology/ecology research.

- Some of the NARS in Africa were eager to cooperate; others took longer to be convinced that they had a problem and that biological control was the solution. It was often difficult to get the countries to issue the necessary import permits for the natural enemies because of fears that the parasites might turn on the crops once they finished all the mealybugs.
- The coordination of all the activities was relatively simple and cost effective. There were only two staff members dedicated to the collaboration efforts, and they were also involved in cooperative research with the NARS. Regional training workshops were held every three years or so in each region (West/Central/East and Southern Africa). Bilateral meetings were held with collaborators from Europe and North and South America. There were only two major conferences on the project, one in 1984 in Ibadan and the other in 1988 at the inauguration of the new IITA-Biological Control Center for Africa in Cotonou.
- Most of the program results were reported in peer-reviewed journal articles. More than 100 have been published to date and more papers are in the making. Many papers on the project have been reported at international conferences, symposia, and workshops. Publication was emphasized so that this biological-control program, unlike many others, will be would documented.

The cassava mealybug project was a research network. It illustrates at one and the same time the globalization of agricultural research, the ways in which scientists work effectively together, and one of the CGIAR's greatest achievements. IITA and CIAT were jointly awarded the King Baudoin award for the project in 1992. The project's leader, Dr.Hans Herren, was awarded the World Food Prize in 1995.

The international agricultural research centers participate in many networks. They are one of the ways by which the centers and the national agricultural research systems of the developing countries work together. The INIBAP, INGER, and PRECODEPA networks are well known to most people who are familiar with the work of the CGIAR. Networks enable scientists from smaller and less well-supported NARS to participate in joint research activities with others from their own and related disciplines. They enable newly qualified scientists to obtain training in the skills of their disciplines.

Many of the networks in which the centers are currently involved are not really research networks but communication networks in which scientists working on common themes meet periodically to exchange information about their projects and learn about new techniques and theories in their fields. Such meetings are helpful, particularly to scientists who have insufficient professional contacts within their own organizations or do not have access to international scientific journals.

More valuable are those networks in which research is the real purpose, in which the scientists who participate undertake research projects within a conceptual framework established to achieve a clearly defined objective, such as the control of the cassava mealybug. Periodic meetings of the participants in these networks are used to provide scientific reports of progress, to critique each other's assumptions and methods, to build up the required body of knowledge, and often, to uncover new ideas regarding the nature of the common problem or its possible solution. Such networks provide synergy and the environment for serendipitous discoveries. They have much greater training value than information networks.

In well-designed research networks, participants can work at different levels—basic, strategic, applied or adaptive—while working together. They can bring together international research centers seeking international public goods, research institutes with specialized talents, national research organizations concerned with national problems, state and local research agencies and universities seeking solutions to high-priority state problems, and nongovernmental organizations and extension agencies working directly with farmers.

Within the CGIAR system, the best known of these research networks are those for the genetic enhancement of CGIAR commodities. The three already mentioned by acronym have such a purpose. The participants are plant breeders, pathologists, entomologists, and agronomists. Such networks represent an effective means for determining genetic-environment interactions. They seldom include basic research studies. They can become routine and indeterminate. Farming systems networks, such as the Asian rice farming network, usually include only applied and adaptive research. Networks that deal with a yield-reducing vector, such as a virus or an insect, generally contain both upstream and downstream components and often include participants from institutions widely scattered across the globe. The barley yellow dwarf network and groundnut rosette virus network are two examples in which international research centers have been deeply involved.

The pundits who have studied networks give the criteria needed for success. They include having an important research purpose or goal; a focused strategy; good coordination, preferably by one or more leading scientists; committed participants; and flexible sources of funding. I would add *a beginning and an end*.

From the cassava mealybug network, we can see the importance of global reach, of matching tasks and talents, of incorporating the results of relevant independent research, of building and retaining commitment among participants and donors, of publishing research results, of keeping the costs of coordination down, and of sharing costs. The cassava network had visionary scientific leadership interested not only in doing the research but ensuring its utilization. Obtaining approval to rear the parasites and distribute them on farmers' fields throughout Africa was probably the most difficult obstacle that had to be overcome.

As pressures increase for the centers to work with more and more partners—from NARS to mentor institutes in donor countries to universities to NGOs to the private sector—networks become increasingly important. They are virtually the only way that the centers can satisfy this diversity of demands upon their time and resources.

What is the goal of globalizing international agricultural research? If it is that the international centers should hand over some of their responsibilities to others, the evidence so far is less than persuasive. Global partnerships set up to tackle and solve big problems using the best available science are likely to be better alternatives. They will not always succeed because research is a risky business, but as the cassava mealybug project amply illustrates, one successful project with major impact can help pay for several that manage only to build up stores of knowledge to increase the probabilities of future success.

About the Author

Leslie Denis Swindale, a New Zealand citizen, was the director general of ICRISAT from 1977 to 1991 and is currently chairperson of the governing board of IIMI. During these years and earlier, as a professor at the University of Hawaii and as chief of soil services for FAO, he learned about the needs and resource constraints of people living in the tropics. For his efforts to help alleviate these problems, he was awarded the Padma Bhushan by the president of India in 1991 and the New Zealand Medal of Science and Technology in 1995.

The Best-Kept Secret

Derek Tribe

The evidence is unanimous and overwhelming. It comes from the World Bank, from the international agricultural research centers, from universities and institutes in all parts of the world, and from scores of individual economists, policymakers, scientists, historians, sociologists, and environmentalists of every nationality.

Listen to what the experts say:

President James Wolfensohn of the World Bank:

Unless we address the issues of sustainable agriculture we will be unable to accomplish our goals of poverty reduction, food security and sustainable natural resources management. We must give the highest priority to the agricultural and rural sector since their neglect means that neither rural nor urban poverty can be reduced.

Vice-President Al Gore of the USA:

What's required now are . . . massive efforts to design and then transfer to poor nations the new technologies needed for sustained economic progress.

Ismail Serageldin, Chairman, CGIAR:

The world's basic objectives of poverty reduction, food security and sustainable natural resource management cannot be met unless rural well-being in general, and a prosperous private agriculture for small and medium size holders in particular, are nurtured and improved. Central to improving the productivity and profitability of agriculture are improved technology, appropriate policies and supportive institutions. At the core of technological improvement is agricultural research.

The Hon. Maina Wanjigi, Former Minister of Agriculture, Kenya:

First and foremost agricultural research must be given a political base that guarantees sustainable political and resource support . . . . We, African policy formulators, must commit ourselves to a future based on continuous technological advancement because there is no alternative.

Dr. Donald Winkelmann, Chairman, TAC:

Historically, new agricultural technologies have been the major force driving improved productivity. Today, such technologies must also protect the natural resources upon which agriculture rests. These technological solutions will come from agricultural research, literally humankind's lifeline to the future.

Robert Blake, David Bell, Jessica Mathews, Robert McNamara, Peter McPherson and Montague Yudelman—The Action Group on Food Security:

Without question, the international community must give a higher priority

> *to providing strong and stable support for international agricultural research aimed at increasing food productivity and protecting the environment.*

And so on, and on, and on . . . .

Yet, no one is listening. Every piece of evidence and experience leads to the conclusion that the world is seriously underinvesting in agricultural R&D.* Worse still, as the evidence has grown during the last 20 years, those who make decisions, nationally and internationally, have actually chosen to decrease these investments further.

The decline of funding support for the global system of agricultural research, including the national agricultural research systems and the CGIAR, has led to serious consequences. In the words of the Committee on Agricultural Sustainability for Developing Countries:

> Key staff are leaving, and attracting the high calibre and highly motivated scientists who have long been the backbone of the system is becoming difficult. The uncertainty has also made planning very difficult and undermined the serious and sustained research effort that is essential in dealing with agricultural problems.

During the last two years, hopes have been high that under the leadership of Dr. Ismail Serageldin, the crisis in the CGIAR could be resolved. Considerable progress has been made in reviewing the structure and governance of the system, but so far, Dr. Serageldin's appeal for *"the re-dedication of the international community, at the highest levels, to this vision of a renewed CGIAR"* has gone largely unanswered. The UNDP, regional development banks, and until recently, the World Bank are also failing to give the levels of support to agricultural R&D that are needed and which their own staff have recommended. The detailed analysis of *The Role of the World Bank in Agricultural Development in the 1990s* (Lipton and Paarlberg 1990) came to the astonishing conclusion that the decline in Bank spending on agriculture during the 1980s was largely unintentional and inadvertent. Meanwhile, funds for the NARS in many parts of the world have been reduced to the point where their effectiveness has been reduced and even their survival is now at risk.

It is not enough only to set up committees, to review and restructure the administration and governance of these systems. What scientists at the coal face need more than anything else are more funds to do more research.

In a logical and sensible world, progress in research would be limited by the availability of good research staff and their original scientific ideas. To limit progress for the want of relatively few dollars is tantamount to criminal negligence. It has been reported that the total annual budget of the CGIAR is equivalent *"to just 8 hours of world defence spending,"* and that most developing countries invest only some 0.5 percent of agricultural GDP in agricultural research.

My vision of an efficient global system of agricultural research, including both national and international activities, is one in which the rate of progress

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*Throughout this article terms like *agriculture* and *agricultural research and development* are used in their broadest sense to include the scientific, economic, and social investigation and improvement of crop, animal, forestry and fisheries management and the associated sustainable use of natural resources.

will no longer be limited by the severe and totally unreasonable shortage of what are genuinely modest amounts of money.

Senior and experienced commentators have concluded that the financial crisis that continues to afflict agricultural research systems is due to *"the complacency and inattention of the systems' donors."* A sorry indictment indeed.

Who are *"the donors"*? Why are they complacent and inattentive? Why is the system starved of funds? What should be done about it?

The Donors

Apart from the Rockefeller and Ford Foundations, whose farsightedness started the global network of international agricultural research, most of the members of the CGIAR are national governments, plus a small number of critically important international agencies and regional representatives.

In the case of the member governments, policies are made by ministers who, regrettably, are largely ignorant of the role and achievements of international agricultural research and who also pander to a mainly urban electorate. At present, most governments allocate less than two percent of their overseas aid budgets to international agricultural research, including an average of less than one-half of one percent to the CGIAR.

Governments throughout the developing world show a similar reluctance to give agricultural research the priority it deserves. A recent regional workshop in Latin America concluded that:

"Despite the demonstrated high payoffs to investment in agricultural research, and its vital role in rural income generation and conservation of natural resources, chronic underfunding threatens the survival of several research systems in Latin America and the Caribbean region".

The situation in most African countries is as bad or even worse.

This appallingly low priority for an activity that gives such critically important benefits is the result of ignorance. Dr. Serageldin has described the role and achievements of international agricultural research as *"one of the best-kept secrets of the world"* and he is absolutely right.

A systematic and comprehensive effort is urgently needed to let this secret out of the bag. This would do more than anything else to secure the research funds that are so urgently needed. Indeed, without such an effort, adequate resources will never be forthcoming—and without adequate resources for research, the new knowledge needed to improve world agriculture will never become available in time to save the millions who are poor and hungry, or to save the environment.

To make people better aware of the role, importance, and achievements of the global network of agricultural research, a strategy is needed that clearly identifies the essential message(s), the priority target(s), and the appropriate messenger(s).

The Message

The essential message is clear, well founded, and irrefutable. It has been analyzed, formulated, and articulated in detail in countless scholarly books and papers. IFPRI's *2020 Vision* provides an excellent, comprehensive, and up-dated version of it.

The imaginative strategy proposed last year to the CGIAR's Public Awareness and Resources Committee by Julian Cribb envisaged that the overall message would rest on five pillars:

1. Food for Peace
   International agricultural research is a powerful and effective means of averting and preventing future conflicts, local, regional and international, over scarce resources of water, land and food.
2. Food for Growth
   Increased rural prosperity is fundamental to national economic growth, which in turn underpins peace, world trade and living standards in all countries.
3. Food for the Planet
   Research into sustainable farming systems is essential for the preservation and enhancement of the Earth's life support systems and is a primary conservation goal.
4. Food for Health
   Better nutrition is essential to saving the lives of the millions who now suffer and die from preventable disease. Food and health go hand-in-hand.
5. Food for People
   International agricultural research is the most effective long-term method to provide sustainable increases in living standards for the rural poor and so limit human population growth.

These five messages should not promote research in isolation or as an end in itself. Rather, they should develop awareness of the importance of new knowledge to improve human welfare—employment, prosperity, health, environmental renewal, the alleviation of human suffering, the status of women, human rights, and ultimately, peace.

Although all messages need to be brief, readily understandable, and as free as possible from scientific and economic jargon, they must have a firm foundation in scholarship. These campaign bullets should be prepared initially by research scientists and economists, but in most cases, they are best fired by others, who are not personally involved in international research but who recognize its value and importance.

The Target

The prime target must be those ministers and their chief advisers who together make decisions on national budgets, expenditures, policies, and priorities. However, decision makers do not work in isolation and are influenced to a considerable extent by community attitudes and pressures. It is therefore essential that a public-awareness campaign should also impact upon other targets, particularly community groups interested in agriculture (those involved in farming, forestry, and fisheries), the environment (conservation groups), development assistance and human welfare (nongovernment organizations), and research (scientists and academics). If campaigns aimed at these targets are to be effective, they also need to be reinforced by a more general media campaign, involving the press, radio, and television. However, the Crawford Fund experience shows that the targeting of decision makers is the most crucial.

It is globally important that the target should include politicians and top bureaucrats in both developing and developed countries. A common excuse of those in developed countries for not increasing the allocation of aid funds for agricultural research is that donor countries like to respond to requests from recipient countries. In other words, if developing countries themselves gave a higher priority to agricultural research and urged donors to increase their assistance for it, such support would be forthcoming. Why, it is argued by ministers and aid administrators, should we alter our priorities when recipient countries do not ask us to do so and, in many cases, are actually cutting their own research expenditures?

Developing countries should be encouraged to recognize the role, achievements, and continuing importance of agricultural research in the development of their own economies. If they demonstrate their own willingness to give adequate support to their national agricultural research systems, donor countries would be more likely to increase their support as well.

It is one of the ironies of the CGIAR system that during International Centers' Weeks, many participants spend their time giving good reasons why member countries should be more enlightened and generous in their support for agricultural research. However, they have a negligible impact because those who sit and listen have to stick to the brief that has already been given them by their political and departmental masters at home. To be effective, efforts to change national policies must concentrate on those who sit at the top.

The Messengers

Political decision makers are best reached individually, and this means that they are best approached by persons who are themselves well known and influential. Such persons as ex-political leaders (e.g., presidents, prime ministers, ministers), members of royal families (including ex-governors or governors-general), retired leaders of the UN and its agencies, famous scientists, business leaders and eminent diplomats or academics need to be recruited and well briefed to undertake this task. They should be well informed, independent, and altruistic, and it is extremely important that they should be untouched by any possible charge of self-interest.

Special interest groups need to be approached by individuals who are already known to be sympathetic to the general aims of the particular group. For example, a past president of a farmers' federation is ideal for a farming audience, while, say, a bishop is more likely to influence the World Council of Churches.

The best way of attracting the attention of the general media, and the mass audience that the media serve, is to use well-known, news-worthy individuals who are known to be interesting personalities. Such persons may come from any walk of life and need not be experts in agriculture or research, provided that they are outstanding *performers* and can deliver the right message.

Whatever the target and the method of reaching it, the key to success is access to good research results and reliable examples of their impact. A clear and intellectually rigorous case has to be prepared to convince those who are going to be the messengers. Only messengers who are genuinely true believers in the importance of global agricultural R&D are likely to hit their targets.

Active research scientists should not and cannot be the messengers. There are at least three reasons why active research scientists should not be expected to run their own public awareness campaigns:

- Scientists are already fully occupied doing their research and it is unrealistic and undesirable to divert them away from this to spend time on public awareness.
- The skills needed in public awareness activities are different from those required in scientific research. Some scientist are good at both, but many lack experience or expertise in public awareness, just as most of those who are good in public awareness lack the qualities of a successful scientist.
- Those involved in public awareness activities lack credibility if they are themselves seen to be the primary beneficiaries of such activities.

In many senses, the messengers constitute a group of *"Friends of International Agricultural Research,"* which is comparable to such organizations as friends of the opera/zoo/museum/university/library, and so on.

For maximum, global impact, a centralized group would be necessary. However, a range of smaller, more sharply focused groups could also be extremely helpful.

For example, a group of *Friends* could be constituted by a particular research center in order to publicize its own particular achievements and to attract additional resources for its own particular purposes. Some years ago, ICRISAT formed an effective *"Friends of ICRISAT"* group in Japan, which is still giving useful support. Alternatively, the focus of a group could be a particular commodity. For example, a group is now being developed to support global rice research, wherever it is done and whoever does it.

Similarly, groups could be established on a geographical basis. For example, the Crawford Fund for International Agricultural Research could be regarded as the *"Australian Friends of International Agricultural Research"* and a network of such groups could be formed on a country-by-country basis. These could be based in either developed or developing countries and could either provide broad support for agricultural research or focus particularly on the work of one national system or a single institute. Recently, an ISNAR initiative resulted in the formation of a Netherlands Support Group for International Agricultural Research. This organization supports agricultural research throughout the world, irrespective of which organization is responsible for undertaking it, and it is entirely self-funding.

Experience shows that all groups, however constituted, are most effective if they function in close cooperation with, but independently from, the organizations they seek to help and support. By maintaining its own identity and independence, any public-awareness group is better able to proclaim the achievements and importance of agricultural research and to encourage, cajole, and pressure existing and potential donors to give greater support to it. However, scientists must provide their *Friends* with the ammunition, which means they must systematically provide well-argued studies of impact.

Can It Be Done?

For at least the last 12 years, the CGIAR has been discussing the importance of public awareness and has been seeking effective means of informing world opinion. Had those efforts been successful, the resources available to the system would have increased. It must therefore be concluded that they have largely failed. Why?

To influence global opinion on an issue like agricultural research is no easy task. It requires hard work, adequate resources, dedication, and flair. There is always an element of risk, and such activities need to be undertaken by those with experience, conviction, knowledge, and judgment. Also, they are activities that are ill-suited to committee control or bureaucratic management. For all these reasons, there are advantages from the point of view of national or international organizations in keeping public-awareness activities at arm's length, while still offering them encouragement and support.

Even though it may remain unsaid, the inevitable implication underlying a public-awareness program is that, in failing to give appropriate priority to agricultural R&D in the past, decision makers have made a mistake. National and international public servants are naturally reluctant either to point this out or to fund others to do so. It is not their job to embarrass their political masters.

With the best will in the world, national and international research systems like the CGIAR find it difficult to develop, fund, and manage effective public-awareness programs. Yet, if such programs are not developed, adequate support for the global agricultural research system will never be forthcoming.

My vision is a world in which *"the best-kept secret"* has been revealed. Listen to what the experts say:

Dr. M. S. Swaminathan:

> *To eliminate endemic hunger at the level of the individual it will be necessary to . . . sensitize and mobilize public opinion through the mass media and to generate appropriate political action.*

Julian Cribb:

It is possible to improve world awareness on this matter, and if we do not attempt to do so then we have failed to discharge our responsibility to future generations and to the planet itself.

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About the Author

Derek Tribe was professor and dean of the Faculty of Agriculture at the University of Melbourne. Ha has acted as a consultant on international agricultural research and development for various national and international agencies and was the foundation director of the Crawford Fund for International Agricultural Research. He is now a senior associate with the Crawford Fund.

The Role of NARS in the Changing Global Agricultural Research System

Eduardo J. Trigo

What we are today starting to refer to as the *global research system* is evolving fast and becoming quite different from what we can consider its origins, that is the "international system" of the CGIAR. Today, and even more so in the future, NARS will have to develop their activities in an environment that is significantly different from the one they originated from. This paper attempts to look it this evolving process and highlight some of its implications for NARS activities as well as for national-international relations in agricultural research. The discussion is organized in three sections: the first section highlights the main lines along which the global system is evolving, the second section is focused on the role of NARS, and the third and final section looks into the future from the perspective of the NARS.

How the Global System Is Evolving

The main strength of the "international system" as we knew it in the 1970s was that it had a clear mission, well-defined targets, and a relatively simple structure with somewhat linear relationships.

The mission was to improve food production as an engine for development and the alleviation of poverty. For both of these objectives, food production was instrumental and agricultural research (essentially genetic improvement in a small number of key crops) was a strategy both for donors and national constituencies. It was quite clear that to effectively feed the hungry, there was no other way but to get them to grow food.

In that context, the following was needed:

- a working mechanism for linking existing technological knowledge at the international level and in the developed countries to the problems facing the less-developed world;
- national agricultural research organizations that could act as "transmission bells," adapting those technologies to the specific conditions facing the farmers in developing countries.

Poverty was essentially a rural problem, environmental issues were still non-issues for most of the world, and the development community was strongly behind active intervention to solve development problems. These were the conditions under which the "global system" that we refer to today started its evolution. In this context, each component had a clearly defined role:

- Donors provided resources.
- The IARCs and the research institutions in advanced countries were responsible for the supply of basic knowledge and strategic and applied research results.
- NARS (in reality the NAROs) were responsible for adapting technologies to local conditions.

Furthermore, efforts on the technological side were often complemented by active agricultural policy interventions, aimed to induce the use of improved seed and capital goods through such mechanisms as overvalued exchange rates, subsidized credit, direct subsidies, and public extension services.

The system worked well whether the objective was development or poverty alleviation—both came together within a single operational strategy, which later became to be known as the Green Revolution. This system produced important results in terms of alleviation of poverty, increased production, and improved productivity. It also helped set the conditions for the continued development of NAROs and, eventually, the NARS in the developing world.

Conditions today have changed, and the global system of the 1990s is very different. Although the priorities continue to be development and poverty alleviation, the nature of the problems is changing. While in the 1960s and 1970s, poverty was a rural issue throughout the developing world, in the 1990s it is much less so. In the next decades, for most of Asia and Latin America, virtually all population growth will occur in urban areas, making urban poverty a growing priority. The situation in Africa is somewhat different in absolute terms, but in relative terms, the rural-urban poverty balance will tend to go the same way. This will inevitably affect priorities and strategies. For many areas of the developing world, the production of food by the rural poor as a strategy to bring together poverty alleviation, agricultural development, and economic growth, which was a key element for the success of the Green Revolution, will become less attractive than it was in the past, as the feeding of the urban poor becomes a more pressing priority politically.

Furthermore, as the free trade agreement expands and consolidates, many countries will increasingly consider depending on trade to meet their food needs, either through agricultural diversification or using their lower labor costs to produce manufactured goods and trade them for food in international markets. Many will consider this an unlikely scenario, but it has already been included in discussions in international fora such as the Lucerne Ministerial-Level Meeting, and some countries are de facto using this kind of strategy.

These changes are important both for what they mean in terms of the demand for technology and for their implications for research priorities and research organization. In many cases, research priorities are already moving away from food crops toward a broader product mix, as diversification strategies become important in the process of economic adjustment and revitalization—and as self-reliance replaces self-sufficiency as the basis for food security. As this happens, donor and national objectives and priorities will not be as convergent and consensual as they were in the past. This is not a minor conflict when it comes to discussing research policy issues at the national level.

A second key change is political. The end of the cold war has created a new environment and priorities for international relations. The whole international system is under review and donors have started to approach development assistance in a different way than they did 20 years ago. The new political balances and relationships emerging from the processes of economic reform are changing the logic and priorities of donor assistance. Development assistance is becoming much more targeted and linked to other issues, such as liberalization of trade or increased economic "efficiency." This, together with donor "fatigue" originating in part in the poor performance of many agricultural projects and the loss of much of the glamor associated with the early successes of the Green Revolution, has made a big dent in the availability of resources for national and international research.

The research agenda itself is changing and becoming more complex. This is in part because of the changing nature of the issues of poverty and food security, but (probably more important) because of growing concerns about the environmental problems associated with agriculture and food production.

The issue is no longer to produce food, but to do it in a way that is not harmful to the environment. And integrating sustainable natural resource management into the research agenda is not an easy and straightforward matter. It not only implies going beyond the limits of the traditional agricultural sciences and building up complex interdisciplinary approaches, but it also implies working with a new (wider) set of institutions in a context where there is still no clearly established organizational paradigm. The difficulties confronted during the past few years by attempts to implement the ecoregional approach is a clear example of these complexities.

At the same time, advances in biology, information sciences, and communication technologies are also changing the "production function" of research and technology development. These advances have somewhat counteracting effects on the organization of research at all levels and, of course, also with respect to international activities and NARS. Advances in areas such as biotechnology have important economies of size and scope, putting small NARS at a disadvantage, while information and communication technologies, by facilitating access to and exchange of information, tend to mitigate these negative effects. The national-international division of labor, NARS-NARS cooperation, and a number of other areas have now to be recast in the context of the opportunities these advances offer. The full impact of this is still to be seen.

These technologies, plus the elimination of policy and institutional barriers to private-sector appropriation of research results and technologies, are significantly altering the traditional public-private balance in research and development activities. As the public-good nature of agricultural research and technology is changing, there is a need to reconsider basic organizational principles, at both the national and international levels.

Together with this evolution, there has also been a very substantive diversification of actors at the national and international levels. From a situation such as the one described above, where there are a few very specialized players (universities and advanced science centers, IARCs, a cast of fairly homogeneous NAROs in developing countries, including some [tropical] commodity research organizations and some private-sector organizations), today there is an ever-widening array of very diverse actors, with some nontraditional ones, such as regional organizations, NGOs, and the private sector, having increased importance. It is in the context of this system, characterized by diversity and sometimes conflicting objectives among its participants, that we have to discuss the role of NARS.

The Evolution of NARS

How have the NARS themselves evolved? NARS are the essential component of this system. Investments in research, at whatever level, are ultimately aimed to improve the conditions of production and productivity, and for that, they have to be able to reach agricultural producers. The NARS are the critical component at this stage. Agricultural technology is location specific, so whatever evolution takes place in the system of scientific and technical knowledge, the capacity to adapt knowledge to local conditions will always be required. Without this capacity, all the work and knowledge available at the global level is almost worthless. This has always been beyond discussion and there are concrete examples of how the presence of effective NARS was the critical element in many of the past successes of international research.

The NARS have also changed over the last 20 to 25 years, and the role they will play in the future is very much affected by the way they have been evolving. In the 1960s and '70s, most NARS shared the same characteristics. There were not many differences among large and small systems, or among African, Latin American, or Asian NARS. All had relatively similar capabilities and limitations and they played essentially the same role vis-à-vis international activities, as well as in their national constituencies.

The situation today is very different and shows a number of contradictory trends. NARS have grown stronger in terms of their human resources in almost every region of the developing world. They represent probably 65 percent or more of the total number of researchers, and the percentage of them holding postgraduate qualifications has increased dramatically. Financial resources have also improved. But the performance here is less rosy than that in the field of human resources. After a relatively long period of sustained improvement in investment levels during the last decade, there seems to be a reversal of the trend. Many systems now confront the contradictory situation of having the human resources and scientific capability to work on the priority problems facing their agricultural and political constituencies, but they lack the operational resources to take advantage of this capability.

This quantitative growth has been accompanied by qualitative growth and differentiation among the capabilities of the NARS. While some have remained essentially organizations for conducting adaptive research, others—usually, but not only, in the larger countries—have added considerable depth to their programs and are now undertaking applied, strategic, and even basic research. Some have become equal partners with advanced research institutions; others have shown little improvement, and in some cases, there have been involutionary processes due mainly to deteriorating political conditions in their countries or regions.

The nature of the NARS has also changed along with the institutional and economic development in their particular environments. From single-organization systems, NARS in many countries have evolved into fairly complex systems with strong participation from universities, NGOs, and the local and international private sector. This evolution is bringing new dimensions into the field of policy and organization. Issues of priority setting and resource allocation, interinstitutional coordination, and research funding (levels, origin of resources, and mechanisms) are also changing accordingly.

But probably the most important issue to consider with regards to the political and institutional environment at this time is a changing perception as to the role of government in society. Current trends to reform the State in many developing countries are seriously affecting the legitimacy of traditional NARO organizations and public investments in research. Many countries are moving toward passive approaches to agricultural policy and are abandoning the "supply-shifters" strategies that have supported public investments in research and extension in the past. This is an on-going trend, and it is still difficult to anticipate the full extent of its implications. However, it is clear that the existing institutional framework for agricultural and rural development is under review and the new paradigm is still not consolidated.

All these issues are having an effect on the role that NARS can or could play within the global system.

Looking to the Future: The Role of NARS

In looking to the future, the events that I have briefly—and most probably, incompletely—summarized point to a system that is increasingly complex and still evolving. The nature of the on-going process of renewal of the CGIAR is clear and evident testimony of this. There are diversified and sometimes conflicting objectives. The objectives of donors and developing countries in many ways do not come together as clearly as they did before. The different regions have different needs and opportunities. There are different types of organizations, and funding conditions are radically different from what they used to be at both the national and the international level. All these aspects have to be considered when thinking of the role that NARS can or should play.

Still, the fact that the NARS constitute the key actor in the game continues unchallenged, as the capacity to undertake applied research and adapt technological knowledge to local conditions continues to be a necessary condition for the success of the system as a whole. The key issue here is that what is implied by that role is also changing. Adaptive research in the traditional sense of variety improvement and the related work in crops and system management is a continuing need. In addition, the NARS have to add to their agendas the capacity to do the following:

- become partners of the IARCs and the regional organizations in implementing ecoregional approaches;
- become "antennas" and intelligent observers and build links to technological opportunities that may be available in the global knowledge market. Many NARS are, as mentioned above, facing more diversified demands; also, the emerging global system implies substantial diversification of the sources of relevant scientific and technological knowledge. The NARS will increasingly need to go beyond traditional linkages and cooperation arrangements, in some cases even looking into arrangements with the international private sector and eventually offering their antenna services to the local private sector as part of what we could identify as a new type of"semi-public-good"—helping national economic actors become "intelligent buyers" of technology.

Beyond these functions, there is increasing differentiation in roles of NARS, depending on the extent of the development of their scientific strengths and capabilities and even depending on the nature of the national and regional economic and political environments in which they operate. Some of the more advanced NARS now have the capacity to assume the responsibilities for strategic and basic research, and they can be expected in the future to increasingly undertake those functions in a collaborative manner with lARCs, advanced research organizations in developed countries, and with other NARS in the developing world. The discussion about the devolution of responsibilities initiated a few years ago should probably be renewed now. In many areas, it is becoming evident that using existing advanced capacities in some developing-country NARS in a regional or international projection will increase the efficiency of resource use, while at the same time freeing IARC resources. This would allow the IARCs to move upstream where they may have greater comparative advantages.

The role, needs, and opportunities facing a particular NARS are also increasingly different, depending on the nature of their regional environment. NARS of a similar nature will behave differently and have different roles, opportunities, and needs in different regional environments. For example, NARS in regions with active political and economic processes of integration will confront different opportunities than will NARS in more fragmented regions or in regions where there are no larger or more "advanced" NARS with whom to interact. The possibilities of exploiting synergies among complementary systems and economies of size and scope are issues directly related to regionalization processes and the opportunities they offer to NARS.

Finally, there is a more political role for NARS in the new global system: that of helping to bring the whole system into focus by effectively voicing their needs. One of the issues discussed over and over again has been the strong belief that the priorities of developing countries are not properly expressed in international research. This problem can only be solved if NARS become more effective in expressing their demands. The current process of renewal of the CGIAR has fully recognized the importance of this issue, and there are concrete proposals already being implemented. However, there is still a lot of tuning-up to be done before these new mechanisms become really effective.

In summing up, prevailing trends point to a situation where all NARS will continue to have a few functions or roles in common, but beyond those, they will become increasingly different, depending on their size and maturity, their location, and other factors. This will have significant organizational and management implications. Different roles mean different types of research, and different types of research need different organizational formats. This is a critical issue that in the past may not have received as much attention as it needed, but which should become a priority in the future.

A final comment: based on the discussion above, I see a world in transition. NARS in the future will be very different from what they were and what they are today. Most likely, we are not on an evolutionary trajectory, but rather in an era of breakthroughs towards a new "vintage" of agricultural research institutions. The logic behind them, as well as the "technology" they use to produce and deliver their products, is changing. So we have to expect these changes to occur—not only as inevitable but as something to be encouraged and supported. The successful NARS in the future are going to be those that find the most appropriate organizational forms and management strategies to exploit emerging scientific, technological, and institutional opportunities. Solutions are going to be very different in each case, and there is a key role to play in helping each country find the one most appropriate for its particular needs and conditions.

About the Author

Eduardo J. Trigo is the founding executive director of the ArgenINTA Foundation in Buenos Aires, Argentina. Since earning his MSc and PhD degrees in agricultural economics from the University of Wisconsin in the USA, he has had a broad range of experience in international agricultural development. He served for eight years as director of the Technology Generation and Transfer Program of IICA in Costa Rica, and before that was senior research officer/head of research at ISNAR. In addition, he has served on a number of boards and panels, including the panel of experts on biosafety convened by the Secretariat of the Convention on Biological Diversity, the board of directors of the International Service for the Acquisition of Agri-Biotech Applications, and the board of directors of the National Technological Modernization Fund in Argentina.

Agricultural Research in the Tropics: Past and Future

Montague Yudelman

The great successes in increasing food production over the past 25 years have highlighted the importance of agricultural research as an instrument of change in raising agricultural productivity. Over the next 25 years and beyond, food production will have to rise substantially in Asia, Africa, and Latin America as an essential precondition for billions of people living in these areas to have food security.

A substantial proportion of the increased supply will have to continue to come from raising yields per acre, which will become increasingly difficult without a steady upgrading of available technologies that can be used profitably by millions of small and medium-sized producers scattered throughout the tropics. As in the past, the underpinnings for any upgrading of existing technology or the introduction of new technologies will have to depend, among other things, on successful research and experimentation, with much of it being conducted in the tropics themselves.

Ideally, a concentrated global effort to generate future yield-increasing technologies in the tropics could be served by an organized approach that would harness and, where necessary, expand available global research capacities. A highly simplified description of such an approach would include some supranational mechanism for establishing priorities based on a common consensus of the importance of any proposed research. There would be pooled resources to implement these priorities. In such a system, research tasks would be undertaken on the basis of the comparative advantages enjoyed by different research systems. Thus, "basic" research would be undertaken in developed countries and in those developing countries with advanced research facilities and a plentiful supply of skilled labor. "Applied" and "adapted" research would take place in national research entities in the tropics themselves. Where desirable, these entities could be consolidated across national boundaries in the interest of efficiency and to avoid unnecessary duplication.

In the late 1990s, however, the great bulk of the current global agricultural research system is based on national interests, rather than any overriding concerns about the needs of those outside of the national purview. At present, much of the world's ongoing agricultural research is funded out of national agricultural budgets, and so, is responsive to the wishes of national farming constituencies (especially in the developed countries). As a result, it is seldom that national research budgets in developed countries include funds for raising the productivity of small-scale subsistence producers in, say, the Mekong Delta or the Sahel.

The funds for agricultural research in the developing countries also come from national budgets, based on some ranking of national priorities. These funds are often supplemented by funds from the aid programs of outside donors. However, it is important to note that external funds are a small part of the total investment in national agricultural research. By way of illustration, global public investment in agricultural research in 1990 was around $17 billion—about equally divided between investments in developed and developing countries. External funding for agricultural research was less than 5 percent of the total, and was less than 10 percent of the investment in research in developing countries in a year when aid for research was relatively high. The point to be emphasized is that almost all the agricultural research in the world at large is funded from national resources in response to national interests, rather than to assist others in raising their agricultural productivity.

The global capacity to undertake agricultural research has expanded substantially since the 1950s. This expansion has included research intended to increase production both in the temperate and tropical zones. Research in temperate zones, in countries such as the USA, Europe, and Japan has been based on the long-standing appreciation that agricultural research can make a significant contribution to raising farm productivity and incomes, as well as to improving the competitive position of domestically produced agricultural products in international markets.

The most notable change in the research landscape in developed countries in recent years has been the very substantial expansion of research undertaken by the private sector to improve the quality of inputs, such as seeds, agrochemicals, and farm machinery, that could be marketed profitably. There have also been large investments to expand research in biotechnology, with molecular biologists joining the ranks of agricultural scientists in generating improved products for use by the agricultural sector. (In 1995, multinational corporations—two pharmaceutical and one seed company—allocated $250 million for agriculture-related research, of which $60 million was intended for research involving biotechnology.) Currently, private-sector investment in agriculture-related research in developed countries exceeds that of the public sector, which had long been the mainstay of innovation in agriculture. It should be noted that the great bulk of both public- and private-sector research in developed countries is intended to serve the interests of producers in the temperate zones with their sophisticated capital-intensive, labor-scarce agricultural economies, and to widen the choice of affluent consumers, rather than to aid poor, small-scale producers and low-income consumers in the tropics.

As yet, there is very little biotechnical research in developing countries, and the transfer of research materials to developing countries is severely curtailed by a lack of clarification regarding intellectual property rights and by concerns about the safety of genetically altered products. The recent expansion of agricultural research capacity in developing countries started from a very modest base, which is part of the colonial legacy of many of these countries. The colonial powers generally assumed that there were plentiful supplies of land and labor, which when combined with traditional methods of production, provided subsistence enough for the largely rural populations. There was no pressure to undertake research on food production for domestic consumption or for export, nor was there any pressure to train agricultural scientists from these countries. (A major exception was the Japanese-sponsored research in the colonies of Taiwan and Manchuria to increase rice production to augment the supply of rice for Japanese consumers.)

The limited research that was undertaken in most of the former colonies in the tropics was managed and executed largely by colonial officials; this research was intended to improve the quality of cash and export crops with a view to increasing revenues for the local administration and to expand trade with metropolitan powers. These cash and export crops included fibers, such as cotton, jute, sisal, and hemp, as well as beverages, such as tea and coffee, and other commodities, such as sugar and rubber. One result of these policies was that by the mid-1950s and early 1960s, most ex-colonies had a very limited research infrastructure and a negligible capacity to handle research on food crops.

A combination of fears of possible food shortages and the demonstrated effect of a successful program to raise yields in the tropics contributed to the rapid expansion of research capacity in the developing countries as a whole in the 1960s, 1970s, and early 1980s. The research program in question was one sponsored by the Rockefeller Foundation, which led to the development of high-yielding, disease-resistant varieties of wheat that could flourish in the tropics. The program, which was executed in large part by a small number of talented American scientists working on-site in Mexico, provided a new paradigm for agricultural development in the tropics that was based, in the first instance, on the products of increased investments in agricultural research. This paradigm—the Green Revolution—centered on the use of newly developed, high-yielding, disease-free varieties of seed, which when used with appropriate agrochemicals and regular supplies of water, generated a much higher yield than the traditional methods of production.

The use of the new paradigm increased Mexican wheat production very rapidly in the early 1960s and, subsequently, provided the basis for increasing wheat yields and production in the populous countries of Asia. The success of the Mexican program and its mode of research led to the Ford and Rockefeller Foundations undertaking a joint venture to develop high-yielding varieties of rice for use in Asia (and subsequently to expand their research elsewhere in the tropics). The rice research carried out in the Philippines was eminently successful and provided the vehicle for substantially boosting rice yields in the irrigated areas of Asia; however, the foundations soon found that the cost of running the international centers and the cost of expanding the system to other regions of the world was draining their resources. They turned to the World Bank to organize and lead an expanded global effort in agricultural research to raise the yields of basic foods produced in the tropics.

The model for the expanded system was to be based on the Rockefeller experience and was to consist of enclaves of research scientists, mostly from industrialized countries, working in different parts of the tropics to generate the technologies needed by farmers to increase food production. The research was expected to raise the yield potential and disease resistance of improved varieties of a range of food crops grown in different parts of the nonindustrialized world.

The World Bank, FAO, and UNDP became the cosponsors of the CGIAR, and they took the lead in arranging for the financing and expansion of the system. A group of experts, including the author, recommended a network of research centers to cover different agroclimatic zones within the tropics, so in effect "globalizing" research on an agroclimatic basis The proposed blueprint was adopted and the CGIAR undertook to organize and manage a global research system to increase food production in developing countries, especially in Asia, Latin America, and subsequently, in Africa. Funding for the system was to come from annual contributions by bilateral and multilateral donors.

The strategy was to expand the model developed by the foundations and to create a number of research enclaves funded by donors through the CGIAR and staffed by highly qualified scientists, mostly from industrialized countries, to develop or adapt products and techniques of production that could increase yields. Where it was feasible and desirable, it was anticipated that the international centers would work with national agricultural research centers, especially in the adaptation of varieties for local production. The CGIAR system grew rapidly and, over time, expanded its mandate, so that by 1996, it incorporated some 16 research entities and had a annual budget of in the neighborhood of $300 million.

Presently, the global system of research can be characterized as comprising three major components:

- Research undertaken in developed countries, including public-sector organizations, nongovernmental research organizations, and tropical research organizations—it should be noted that the USA, with the largest research establishment, has an annual agricultural research investment of about $6 billion, with 23,000 PhDs backed by 45,000 other PhDs working at the more basic end of the spectrum.
- Research systems of developing countries—the national agricultural research systems of developing countries encompass research institutes, universities, local nongovernmental and farmers' organizations, and private firms. There are now more than 50,000 qualified research scientists in China and at least 25,000 in India, and more than 1,000 each in a number of medium-sized Latin American countries, as well as in Nigeria and South Africa.
- International research organizations, including those of the CGIAR and other international institutions, such as IBSRAM and ICIPE—the CGIAR currently employs around 1,000 scientists.

While it is very difficult to quantify agricultural research capacity, one estimate is that the industrialized and developing countries each have around 48 percent of the global research capacity, while the CGIAR has about 4 percent.

This estimate highlights the rapid expansion of capacity in the developing countries—mostly the larger countries—and the relatively small size of the CGIAR system. However, even though the capacity of the developing countries is estimated to be close to that of the developed countries, the task confronting developing-country research systems in increasing food products in the tropics is far more formidable than the tasks the industrialized countries face. Also, the fact that the CGIAR only constitutes 4 percent of the research capacity in no way reflects the true influence of the international agricultural centers and their role in helping to develop new products for use in the developing countries.

Looking to the future, it is very difficult to foresee any true globalization of research that involves pooling resources, establishing international priorities, and allocating research responsibilities. Rather, it is likely that the major research efforts in developing countries will continue along current lines, with public-sector efforts being dominated by national priorities and private-sector efforts being based on opportunities to make profits. There will continue to be "cross-fertilization" of ideas through the current networks of researchers and some consolidation of research in regional settings as there are moves toward greater cooperation among national entities, e.g., in the European Community and, in part, in Southern Africa.

The main external support for national research in the tropics will continue to be through bilateral and multilateral aid programs, including the CGIAR. However, this external support will continue to be a relatively small part of the total annual investment in research. In the short run, the CGIAR can continue to serve a valuable function in undertaking its own research programs, as well as serving as a bridge between researchers in developed and developing countries (and as a major repository of the global supply of germplasm of a variety of food crops).

The CGIAR has been successful in direct involvement in research during its first 25 years of existence, but the creation of its international agricultural research centers was premised on the need to fill a vacuum arising from a shortage of research capacity in the national research systems themselves. The capacity of national research systems—especially in Asia and Latin America—has expanded, so many of these countries now have the institutional base to undertake the research needed to raise productivity in the food sector. In light of this change in circumstances, it would seem reasonable to expect that the focus of external assistance from bilateral and multilateral donors, including assistance channeled through the CGIAR, should be shifted to emphasize strengthening the national agricultural research systems in developing countries. Whatever the fate of the donor-supported CGIAR, the national research systems will be the mainstay of research in the tropics during the 21st century.

In conclusion, it should be recognized that there was a sustained increase in research capacity in the developing countries during the 1960s and 1970s, such that now, the overall capacity of public-sector research in these countries is about equal to that in developed countries. Governments in all parts of the developing world have expanded their research capacity, leading to a substantial increase in the geographical spread of agricultural research in what might be termed the "horizontal globalization" of research. At the same time, the CGIAR has developed a system of international agricultural research stations that focus on research in different agroclimatic zones, which in a sense, also extends global coverage among the developing countries. Other components of the globalization of research in the CGIAR might well include attempts to link the basic research undertaken in developed countries with appropriate researchers in the international agricultural research centers who are interested in the "downstream," aspects of this research. Another global approach of importance is the CG's intention to focus on important transitional issues, such as difficulties in increasing yields in the vast rice/wheat-growing areas of Asia.

However, whatever the strategy adopted by the CGIAR and aid donors, it has to be recognized that in the longer term, raising food production in the tropics will depend mostly on national efforts, including national agricultural research, rather than on global efforts.

About the Author

Montague Yudelman has been involved in international agricultural development for close to 50 years. He was on the staff of the Rockefeller Foundation during the gestation of their international agricultural research program, and later, as the director of Agriculture and Rural Development at the World Bank, he was involved in the planning for and creation of the CGIAR. Dr. Yudelman retired from the Bank in 1973 and is currently a senior fellow at the World Wildlife Fund for Nature in Washington, DC.

The International Service for National Agricultural Research (ISNAR) assists developing countries in bringing about lasting improvements in the performance of their national agricultural research systems and organizations. It does this by promoting appropriate agricultural research policies, sustainable research institutions, and improved research management. ISNAR's services to national research are ultimately intended to benefit producers and consumers in developing countries and to safeguard the natural environment for future generations.

ISNAR offers developing countries three types of service, supported by research and training:

- For a limited number of countries, ISNAR establishes long-term, comprehensive partnerships to support the development of sustainable national agricultural research systems and institutions.
- For a wider range of countries, ISNAR gives support for strengthening specific policy and management components within the research system or constituent entities.
- For all developing countries, as well as the international development community and other interested parties, ISNAR disseminates knowledge and information about national agricultural research.

ISNAR was established in 1979 by the Consultative Group on International Agricultural Research (CGIAR), on the basis of recommendations from an international task force. It began operating at its headquarters in The Hague, the Netherlands, on September 1, 1980.

ISNAR is a nonprofit, autonomous institute, international in character and apolitical in its management, staffing, and operations. It is financially supported by a number of the members of the CGIAR, an informal group of donors that includes countries, development banks, international organizations, and foundations. Of the 16 centers in the CGIAR system of international centers, ISNAR is the only one that focuses specifically on institutional development within national agricultural research systems (NARS).

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